ILLINOIS CONFERENCE ON SOIL CONSERVATION AND WATER QUALITY

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ILLINOIS CONFERENCE ON SOIL CONSERVATION AND WATER QUALITY

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ILLINOIS CONFERENCE ON SOIL
CONSERVATION AND WATER QUALITY

Conference Proceedings

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HISTORICAL CHANGES IN ILLINOIS AGRICULTURE

Robert D. Walker, Professor and Natural Resource Specialist
Cooperative Extension Service, College of Agriculture
University of Illinois

Illinois agriculture continues to change as it has since about 1800, when the agricultural settlers began to come into Illinois in significant numbers. This change continues today as agriculture and our economy responds to ever increasing population pressures, technology within and outside of agriculture, world demand for resources, etc. I plan to discuss a few of these changes that have occurred and will attempt to relate them to our soil resource and soil erosion in particular.

Over the last 300,000 years, there has been a succession of climactic events that influence our lives today in many ways. Ice sheets of continental proportions formed in subpolar regions of North America on at least four different occasions. My discussion today will only deal with the two most recent glaciers to cover parts of Illinois.

About 125,000 years ago, the Illinoian glacial period started, and it ended approximately 30,000 years later. This glacier covered about 80 percent of Illinois, reaching as far south as the Shawnee hills area, near Carbondale and Harrisburg. The landscape after the Illinoian glacier receded was level except for the large valleys cut by glacial melt water. The land may have been leveled by the glacier as it sheered off hills like a giant bulldozer. Or maybe all of the valleys were filled with mud, or maybe it was a combination of the two processes. But whatever the process, we can see the level land that resulted as we drive through the southern half of Illinois today.

The most recent ice sheet to enter Illinois was the Wisconsin glacial period, which started 60 to 70,000 years ago and left the state perhaps as recent as 10,000 years ago. Approximately one-third of the state was covered by this ice sheet. The Wisconsin glacier seemed to have several stages of receding and advancing, leaving moraines or ridges of glacial deposits that account for much of the sloping land in northeastern Illinois today. The ridges also left large areas of trapped water that formed shallow lakes, which later filled in and created areas of flat land between the moraines.

As a result of past glaciers, half of the Illinois land is level, which means it has slopes of 0 to 2 percent. Twenty-two percent of our land has slopes of 2 to 5 percent and 38 percent of our land has slopes exceeding 5 percent.

The succession of glaciers also affected our present-day land through deposits of very fine, windblown glacial rock materials, often referred to as glacial flower or loess. Huge amounts of very fine rock materials were carried out of the glacial area by melt water, and was deposited in the river

valleys. The water flow stopped when the winter temperatures dropped. Then the fine rock material deposited in the river valleys was picked up by strong winds during the winter months and deposited on the land downwind. Through the centuries, over several glacial periods, loess deposits accumulated with depths that were about 30 feet along the bluffs of the Illinois and Mississippi Rivers and that thinned out to less than 25 inches in northeastern Illinois. Soils formed from loess are some of the best found in the world because of their uniform soil textures, freedom from rocks, and excessive clay.

Southern Illinois soils are much older than northern Illinois soils because of the time difference of the two glaciers. Much of the limestone and plant nutrients have leached from the southern Illinois soils over the past 100,000 years. Clay materials have been carried downward in the soil profile, forming a clay layer at 20 to 24 inches, restricting root development and causing internal drainage problems. Southern Illinois soils are subject to more soil erosion because of the poor internal drainage and high rainfall intensities.

Another major difference in soils depends on the native vegetation. Nearly two-thirds of the state is soils developed under grass prairies and about one-third developed under forests. Prairie soils have a much thicker layer of organic-matter accumulation which provides more nitrogen and greater resistance to soil erosion.

Soil erosion becomes more severe as both slope steepness and slope length increases, and as soil permeability decreases. Forest organic matter developed in the top few inches of the soil and was mixed with the lighter color subsoils as the land was plowed. The areas of the state that were not covered by glaciers are subject to the greatest amount of soil erosion because of their steeper topographic characteristics.

Settling the State and its Impact on the Soils

French priests founded Cohakia, the permanent town in the Illinois region in 1699, and Jesuit priests founded Kaskaskia in 1703. However, it was not until the very late 1700's that settlers moved to Illinois in significant numbers. The total population on Illinois was only about 2,500 in 1800 and 12,000 in 1810 but it increased to 55,000 by 1820. When Illinois became a state in 1818, the capitol was located in Kaskaskia, and most of the people lived in the southern third of the state.

In the days of pioneers, farms were nearly self-sufficient and small — 70 to 80 acres. This was about all a man could clear and tend with his crude hand tools and oxen.

While the unglaciated area of Illinois was covered with trees, the hilly land easily eroded after clearing. By 1900, the topsoil on many southern Illinois slopes had eroded away. Erosion was so severe that the University of

Illinois, College of Agriculture purchased 18 acres of abandoned land in 1906 in Johnson County to study land reclamation. Results of the studies were reported in College of Agriculture bulletin number 207, "Working of Soils and Methods of Preservation", published in 1981. Except for 3 acres, this area had been abandoned because so much of the surface soil had been washed away, and there were so many gullies that further cultivation was unprofitable. Here is a statement from Bulletin 207. "Tillage — probably nothing that can be done to rolling land damages it more seriously than faulty methods of tillage. This is a fact which the farmers of Illinois have not yet learned. The direction of plowing, planting, cultivation is usually determined by convenience alone, regardless of consequences. Plowing is more frequently done up and down the hill than any other way, making of dead furrows in this direction affords the best possible beginning for a gully."

I have been told that the Pearl gully in Pike County was started by a dead furrow. This gully now covered over 200 acres.

Although southern Illinois soils are not as fertile as the prairie areas of central and northern Illinois, corn yield figures compared favorably through the late 1800's and early 1900's. By 1930, however, corn yields had fallen below the state average. The average corn yield for Pope County from 1926 through 1936 was 21.1 bushels per acre while the state average increased to 32.6 bushels per acre. Wheat was a popular crop in southern Illinois in the early 1900's and through World War I, but it was abandoned on many southern Illinois farms by 1930 because of poor yields.

After 1850, the advent of the steam engine, steam-powered mills, and the McCormick reaper, Illinois became an important wheat producing area. The agriculture shifted to a wheat economy, and barter gave way to cash trading. On sloping land, particularly in southern Illinois, as farmers grew richer, their soils grew poorer. More and more acres were cleared of tree cover and increasing amounts of marginal lands were brought into cultivation.

Following 1920, as Europe rebuilt its war-torn agriculture and set trade barriers against imports, the American agricultural export market dried up. Prices fell. To compensate for lower prices and to meet the expenses and debts of an overly optimistic expansion spawned by better days, farmers resorted to even heavier cropping; but the land did not respond. The end result was many broke farmers, thousands of acres of abandoned land, and much land bought by the Government in what is now the Shawnee National Forest.

Dixon Springs Research Center

The University of Illinois Dixon Spring Research Station was started in 1933 to learn how to improve crop yields and farm income on hilly and highly eroded soils. The first step to increase production was to apply scientific knowledge. Limestone was removed from the nearby hills, crushed, and applied to the very acid soils. Rock phosphate was added to the phosphorus poor soils. Forage crops were seeded as pasture for beef and sheep. Gullies were

bulldozed in on the steep hillsides, fertilizer was added, and the land was seeded to pasture.

Crop production increased and soil erosion decreased. Annual beef production increased at Dixon Springs, exceeding 450 pounds gain per acre. If you go to the Dixon Springs Station today, you will find the hilly land protected with a grass legume cover for beef and sheep and row crops grown in the creek bottoms where soil erosion is not so severe.

A similar program was implemented by farmers on thousands of acres of hilly land in Illinois, Indiana, Kentucky, and Tennessee. However, in recent years, many of the beef herds have been sold and the land planted to corn and soybeans because of the low profit margins for beef cow herds. In place of the forage crops, attempts are being made to control soil erosion on steep land by planting with no-tillage. However, no-till corn is not as effective in controlling soil erosion as growing forage crops.

Illinois prairie settlers attempted to settle the prairies of Illinois, but they found the root development and mass of growth almost two much to handle until the cast iron plow became available beginning in 1814. The cast iron plow broke the prairie well enough in the first year it was used, but the large amount of decaying organic matter found on the second season stuck to the cast iron like paste. It wasn't until John Deere started mass producing the steel plow after 1837 that farmers were really able to cope with the prairie.

<u>Draining the Swamps</u>

Nearly 3 million acres of Illinois land were either covered with swamps or had such poor drainage that crops could not be grown. Drainage was first based on the law of natural drainage, which did not adequately meet the needs of landowners in many parts of the state. This was particularly true in the flat prairie areas and in river bottoms, where both drainage and flood protection were needed.

Vast acreages of swamps and wetland were avoided by early settlers. The following quote from Ralph Hay on the Vermilion River basin of east central Illinois helps to understand the early wet prairie: "When Illinois became a state in 1818, and for a decade afterwards, during which early settlers came in, east central Illinois was a wide flat swampy expanse covered with big bluestem and other swamp grasses. Settlers described vast ponds covered with green scum, swarms of mosquitoes, cholera, milk sickness, ague, and fever. They considered the land worthless. An early resident refused to trade his riding horse and saddle for 640 acres, valued in 1974 at about one million dollars."

The Farm Drainage Act and Levee Act were passed in 1879 to cover inadequacies of the drainage rules and to give landowners a means of securing proper drainage. The laws permitted drainage district organization with a system of

assessments that permitted districts to include only benefitted lands. It also gave drainage districts the right to extend drains across lands owned by others. However, the drainage work must be done at the expense of the landowners who are benefitted; the water must outlet into a natural water course, and payment for damages must be paid to those landowners who did not receive benefits but had to allow the construction of drainage ditches for outlets on their land.

Millions of acres of Illinois land were drained under these laws. The drained land is highly productive today and soil erosion is seldom a problem. However, flooding may occur. This land will continue to produce for centuries with reasonable care and drainage maintenance.

Major Field Crops

Illinois farmers grew 6 million acres of corn back in 1870, and the acreage increased to 10 million acres in the early 1900's. The acreage has continued at between 8 and 12 million acres (Figure 1).

Soybeans are the second major Illinois crop today. However, before 1930, most of the soybeans were grown as hay. Research in the 1920;s produced better oil seed varieties and the result has been an increase from less than 1 million acres in 1930 to 9.7 million acres by 1979 (Figure 2).

About 2.5 million acres of wheat were grown in 1870. The wheat acreage reached nearly 4 million acres by 1880 and again during World War I (Figure 3).

The oat acreage increased to over 4 million acres by 1900, then stabilized until 1930 when soybeans were introduced and has declined to about ½ million acres (Figure 4).

The hay crop continued at near 3 million acres until 1940 and has declined to near 1 million acres (Figure 5).

To summarize the crop acreage change, the combined acreage of corn and soybeans has increased from about 10 million acres in 1930 to over 20 million acres. Soybeans have replaced oats and hay in the Illinois crop rotation. The most significant change in Illinois agriculture that increased soil erosion on sloping Illinois cropland has been the shift from oats and hay to soybeans.

Crop Yields

Yields of all major crops in Illinois have increased since 1870 with the greatest increases coming since 1940. Oat yields have doubled (Figure 6). Hay yields have tripled (Figure 7), and wheat, soybeans, and corn yields are now 4 times greater than they were in 1870 (Figures 8, 9, 10). This increase in crop yields has reduced soil erosion. Any production practice that I can

think of that increases crop yield will decrease soil erosion when all other factors remain constant. If we compare the soil erosion on an acre of land growing 30 bushels of corn per acre to an acre growing 75 bushels per acre, with all other conditions held the same, soil erosion will be cut in half on the high yield acre. However, this decrease in soil erosion from increased crop yield has not reduced the total soil erosion in Illinois because of the switch from small grains and hay to soybeans.

The great increase in crop yields had another important affect not generally recognized until very recently. We often talk about the yield reduction caused by soil erosion. With crop yields going up in the 1950's and 60's, how could soil erosion be a problem? The crop yield increases brought about by improved technology, increased inputs, and better management had masked the effect of soil erosion on the soils most susceptible to erosion. (The technology and inputs included limestone, nitrogen fertilizers, other fertilizers, chemical weed control, improved insect and disease control, better crop varieties, hybrid seeds, early planting, etc.) Yields have not gone down on highly eroded soils; in fact, they have increased. But the present day yields and potential future yields on most of these soils has been reduced by soil erosion.

Intensive Cropping

The change from a corn-soybean-small grain legume rotation to continuous corn or a corn-soybean rotation was made possible when low-cost nitrogen fertilizer became available. It was no longer necessary to grow legumes for the nitrogen. The shift to corn and soybeans increased the potential for soil erosion.

There are many factors that account for the great increase in corn and soybean acreage in Illinois. Certainly, increase export demand must be at the top of the list, but many more subtle factors were also affecting crop acres.

For instance, the gasoline revolution had its impact. Tractors using modern gasoline engines replaced horses after World War I. Because we did not need the oats and hay to feed horses, more corn and soybeans could be grown. Increased tractor power after World War II enabled Illinois farmers to plant their crops earlier and take full advantage of better crop varieties, fertilizer, and other technology. The must larger and more powerful tractors also enabled farmers to pull the moldboard plow and other implements faster, pulverizing the soil more than with previous equipment. Overworking the soil resulted in greater soil erosion on sloping land.

However, the increased tractor power has perhaps worked to our advantage in recent years. The larger tractors with over 100 horsepower has enable farmers to pull chisel plows large enough to plow out the wheel tracks and to pull the chisel plow fast enough to properly break up the soil. The result has been a major substitution of the chisel plow for the moldboard plow.

While some conservationists are concerned that we are not leaving enough crop residue on the soil surface to satisfactorily control soil erosion on sloping land, we still have received benefits for reducing both wind and water erosion on many acres. Soil erosion can be further reduced by leaving more crop residue on the soil surface where it is needed to control soil erosion.

Transportation

Perhaps the most important reason why the Illinois crop rotation has become so intensive is because of the transportation advantage for exporting products. Of all the Corn Belt states, Illinois is the closest to New Orleans, our major world exporting grain seaport. In addition, transporting grain by river bridge is the lowest cost, on a per mile basis, of our inland transportation systems. The Illinois, Ohio, and Mississippi Rivers and the distance to New Orleans provides Illinois farmers with the lowest cost for grain transportation of any major Corn Belt grain-producing state. Grain prices at the river ports in Illinois are about 5 to 10 cents per bushel higher than prices paid at distant elevators, and prices paid for grain at the elevator are generally 25 to 50 cents per bushel higher in Illinois than for our competitors in northeastern Iowa.

The higher Illinois grain prices has provided more income to Illinois grain farmers. But, it has discouraged both beef and dairy operations that can use forage crops to provide more soil erosion protection to our erosive land (Figure 11). The high grain prices back in the mid 1970's, when Russia was importing record amounts of feed grains, had impacts on Illinois agriculture that continue today. Perhaps it gave incorrect signals about export demands for the years to come. The double-digit inflation also encouraged the purchase of land as a hedge on inflation. In the 1980's, many Illinois farmers and landowners have increased the acres of grain production in an attempt to pay off debt and to hang on. Perhaps we are in a period similar to that which existed after World War I when our export expectations were greater than our actual export demand.

The number of Illinois farms has decreased from about 250,000 in 1910 to about 100,000 in 1980, resulting in larger farm units. This has resulted in more efficient farms but I have no reason to believe that soil erosion is either greater or less as a result of increased farm size.

Summary

Our present state policy is to control soil erosion and to provide food and fiber for present and future generations. Controlling soil erosion will require a change in farming the gently sloping and steeper land. We will not be able to control soil erosion on our steeper land and continue to grow continuous corn and soybeans, even with no-till methods. Grasses and legumes will be required. But, can we grow grasses and legumes profitably? Hay yields do not reflect the adoption of forage production technology as reflected with grain production. I am told by agronomists that we can grow 8

to 10 tons of alfalfa per acre on our best land and 5 to 6 tons on most of our soils. Increasing our current forage production to these levels will make forage production more competitive with grain production, provided that our beef or sheep production is expanded to use the forage or better hay markets are developed.

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FIGURE 1

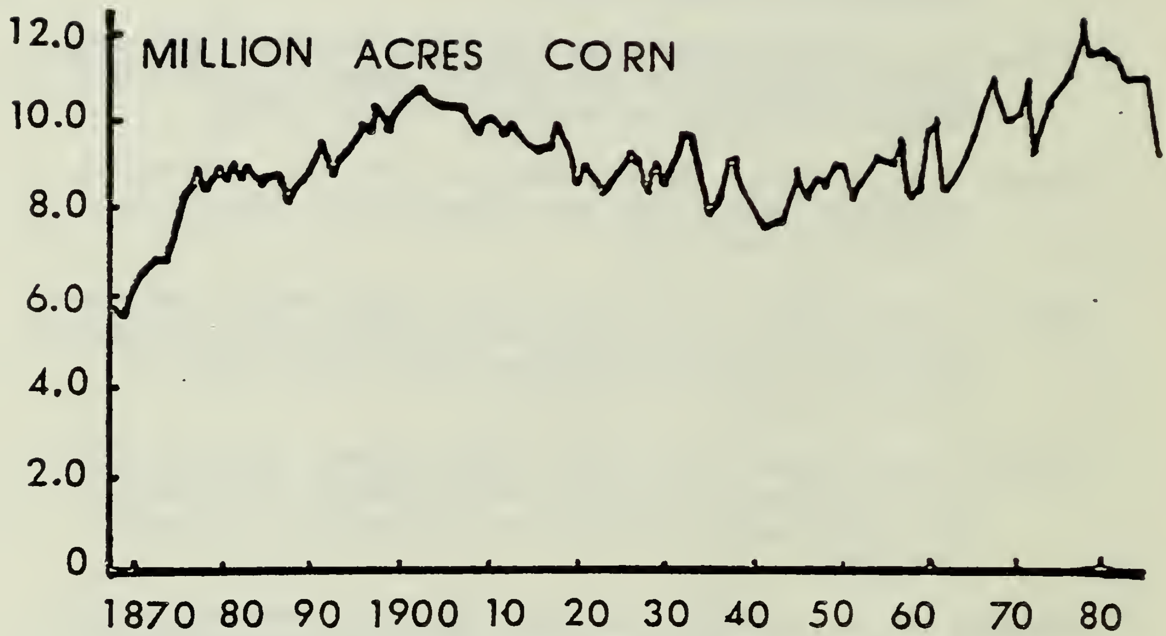

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FIGURE 2

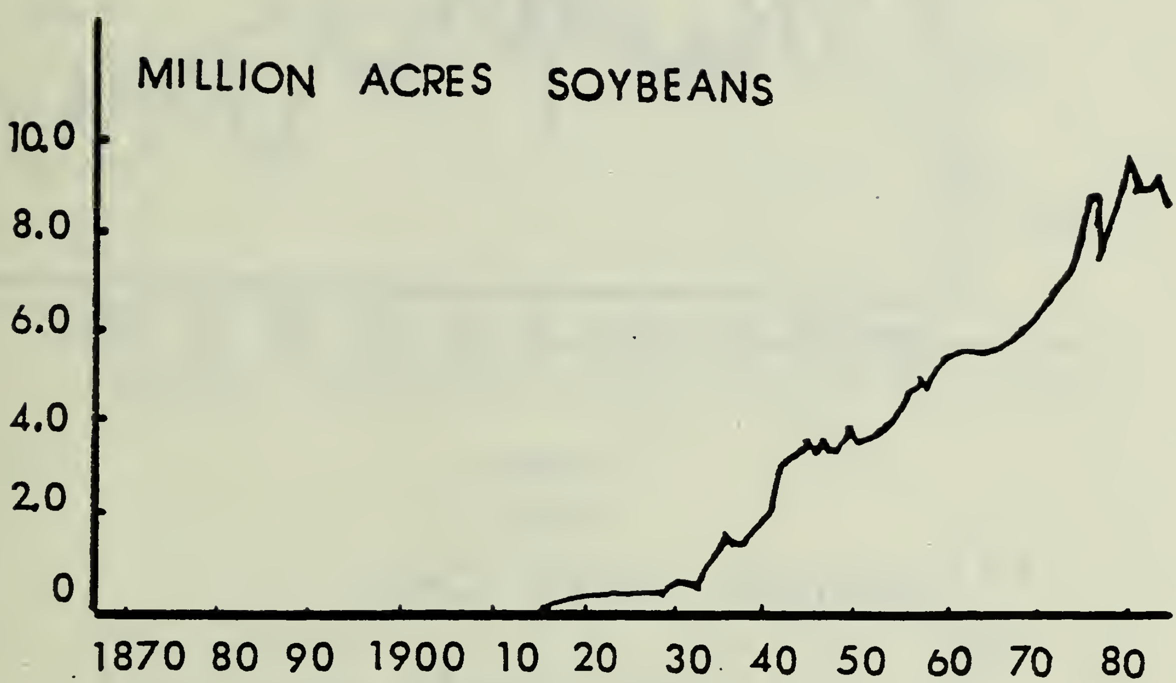
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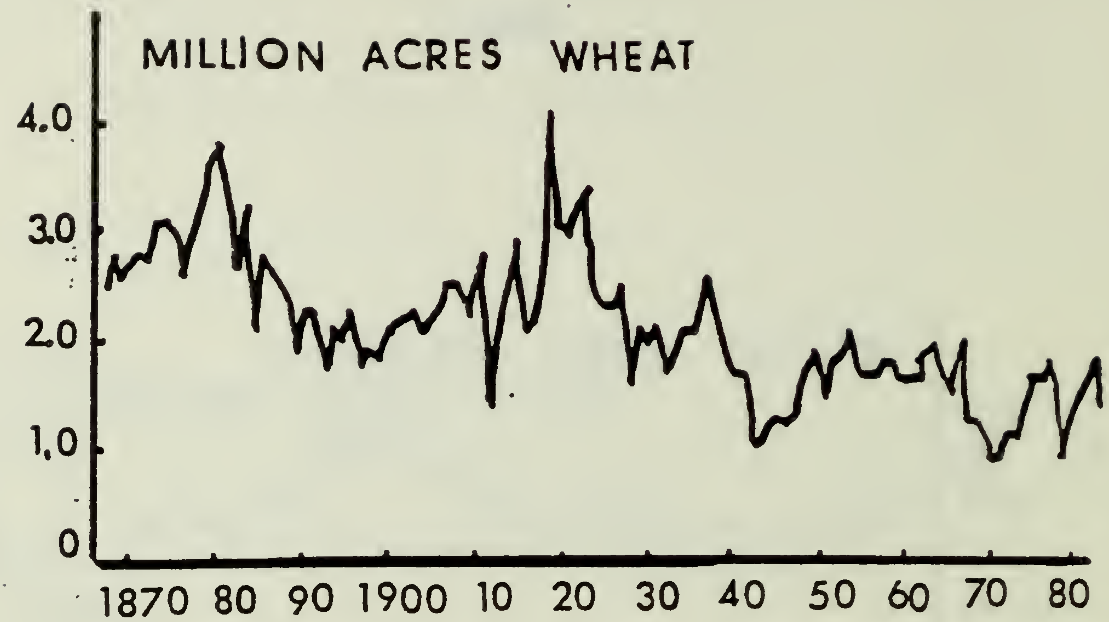
FIGURE 3



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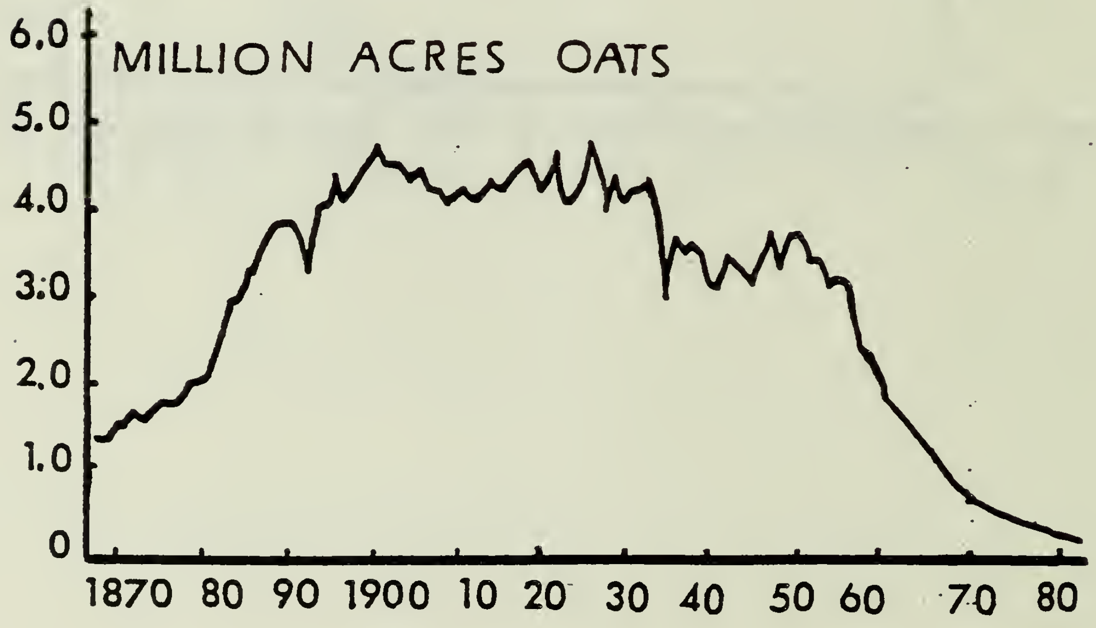

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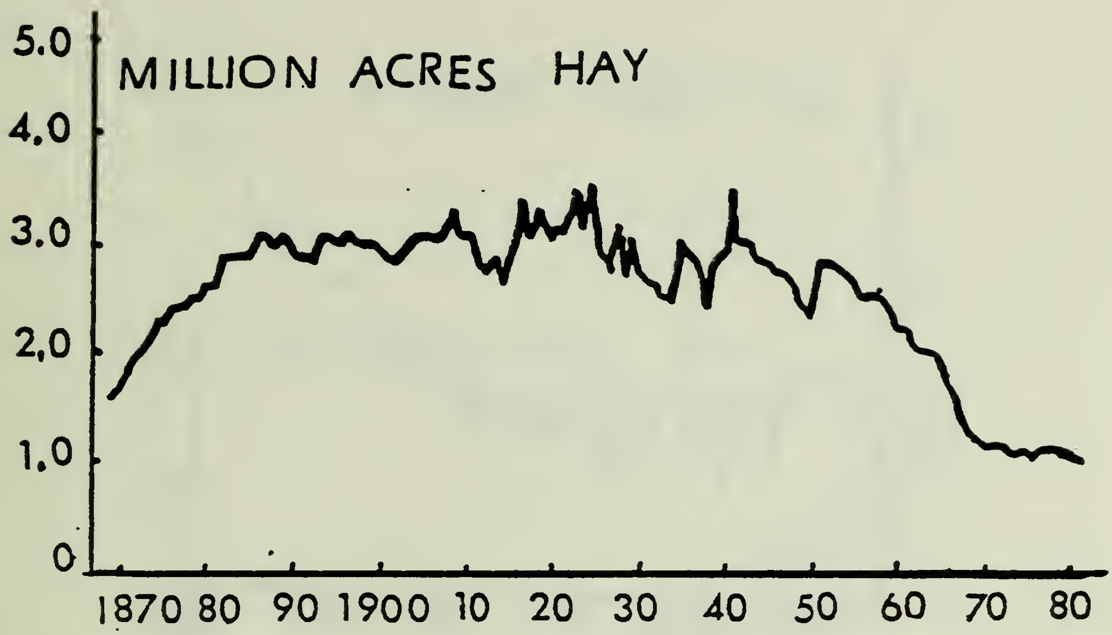

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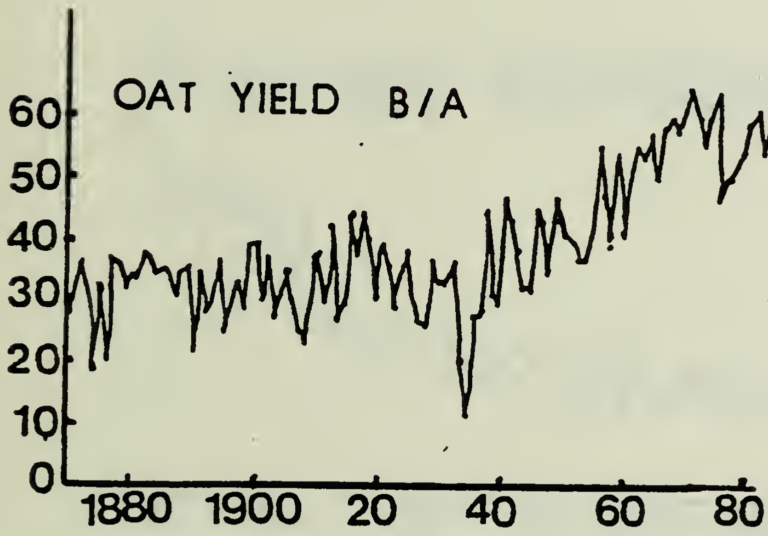

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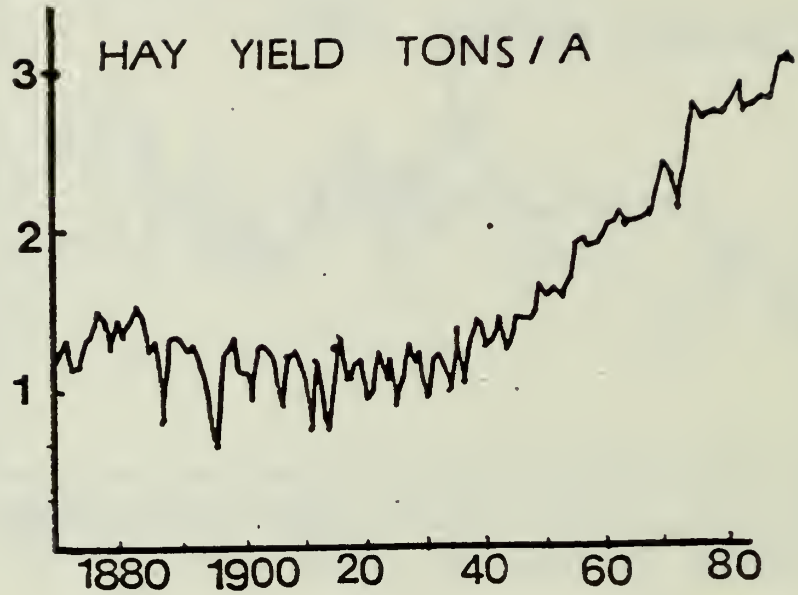

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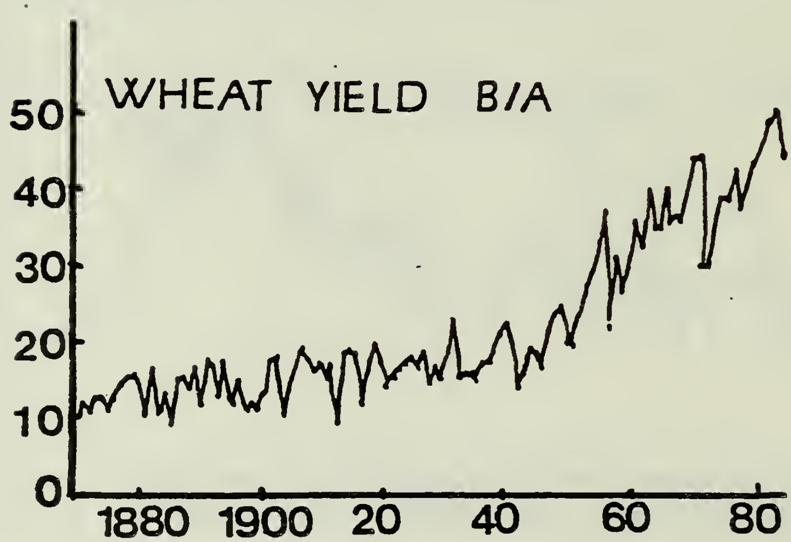

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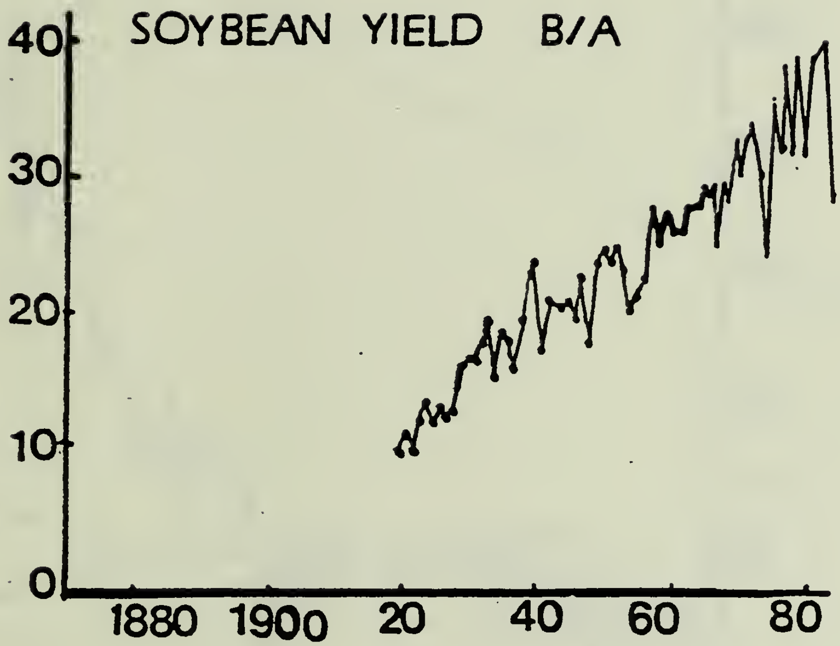

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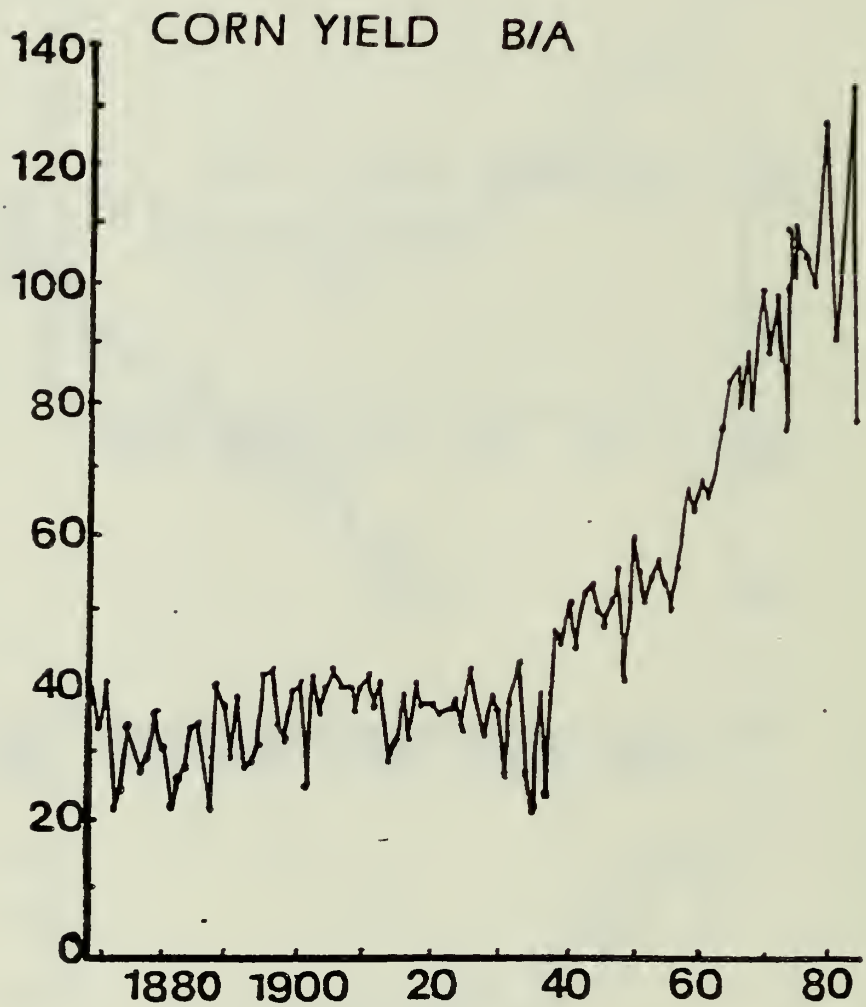
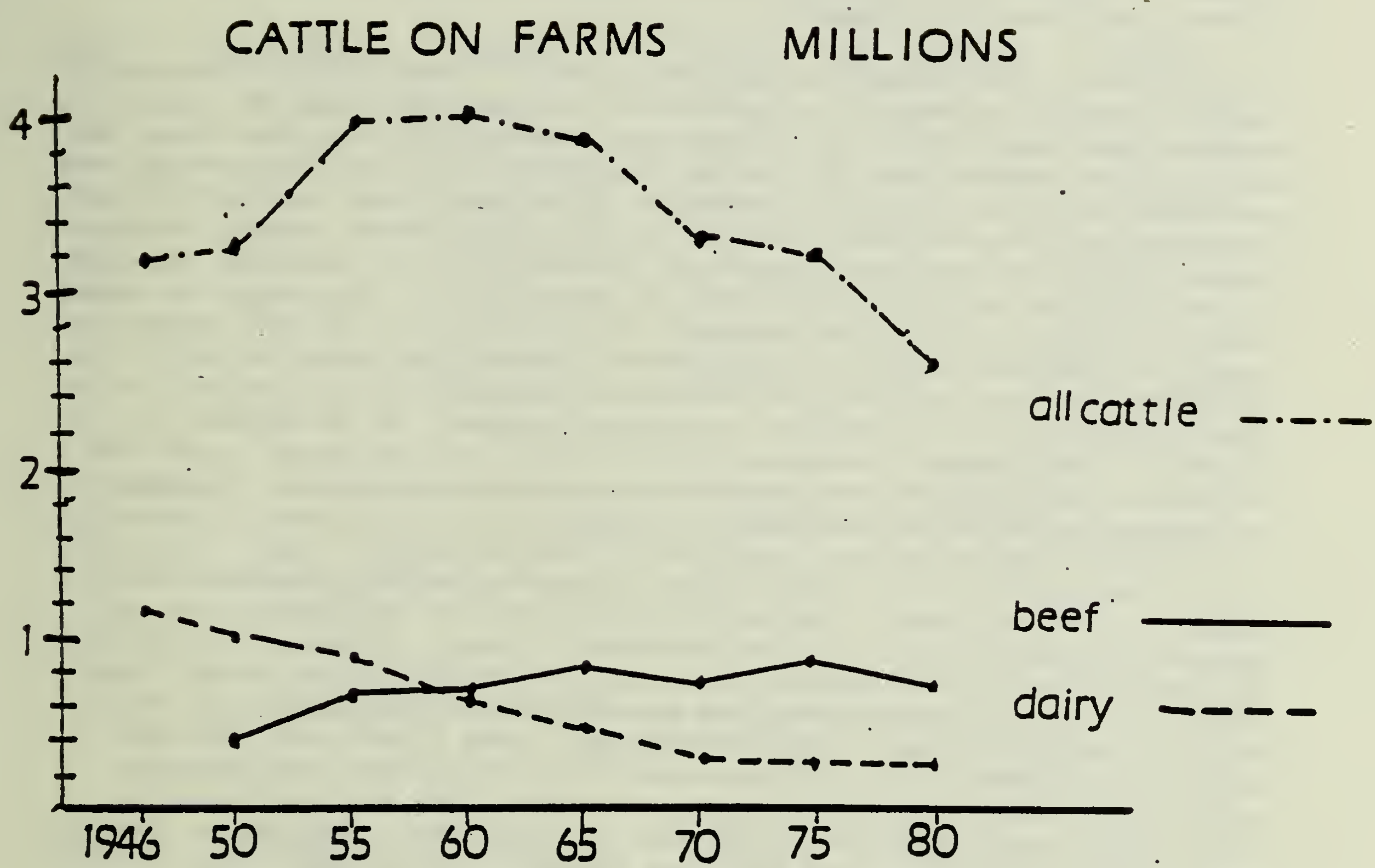


FIGURE 11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all cattle
beef
dairy

The Public Policy Background of Soil Conservation Programs in Illinois

James F. Frank, Superintendent
Division of Natural Resources
Illinois Department of Agriculture

The purpose of this presentation entitled "The Public Policy Background of Soil Conservation Programs in Illinois" is to acquaint the audience with the historical perspective of soil conservation programs that have operated within the state, their funding levels, their policy directions, and a view of what the future might hold.

"Unfortunately, the farmers in many localities are doing little or nothing to stop the wastage and much to accentuate it. In many instances the farmer does not know just what to do to slow down erosion. In many other cases he does not even suspect that the waning productivity of his fields results from any cause other than a natural reduction of the plant foods supplied by the crops removed. He does not recognize the fact that gradual erosion working unceasingly and more or less equally at all points is the principle thief of the fertility of his soil until spots of subsoil clay or rock begin to appear over the sloping areas." Unfortunately this statement is as true today as when it was written in 1928 by Hugh Hammond Bennett the father of soil conservation. He wrote this in a United States Department of Agriculture circular entitled, "Soil Erosion, a National Menace." As the popular cigarette advertisement proclaims, "we've come a long way, baby" since 1928 in terms of technologies used to combat the soil erosion menace. However, the problem is still very much with us today.

In 1933 the nation's third soil erosion control project was begun in the Sangamon River Watershed. This was the first project for Illinois and was located in McLean County near the small town of Leroy, Illinois. The project was comprised of 150,000 acres of dark colored glacial prairie soils. This project was set up in the form of an erosion control camp similar in many ways to the forestry camps set up by the CCC. Just a year after the soil erosion camps were begun in Illinois came the greatest and most effective awareness campaign for soil erosion control ever. The dust bowl years of 1934 and 35, when dust storms big enough to retain their identity as they swept across the country from the great plains to the Atlantic Ocean and 300 miles beyond, descended on New York and Washington, D.C. There they blotted out the sun, sifted through the windows of skyscrapers, and landed on the desks of Washington Congressmen. In 1937 President Roosevelt submitted to the governors of the states a standard Soil Conservation District Law. Twenty-two states adopted it that year and work began with interest in soil conservation districts. Illinois passed its district law on July 9, 1937. One year later on July 22, 1938, the first district in Illinois was formed in St. Clair County. By 1940, 89 of the present 98 Soil and Water Conservation Districts had been formed and in 1959 Sangamon County became the last district to organize.

With the proliferation of legislation at the federal and state level came a new commitment to provide public funding for soil conservation programs. In 1933, the Soil Conservation Service placed three staff persons in Illinois to work on the Sangamon River Watershed Project. Since that time, the number of Soil Conservation Service staff persons has increased substantially; however, the numbers have held fairly static over the past several years even though budgets have increased as indicated in Table One.

TABLE ONE

Soil Conservation Service Staff

Year	No. of Staff	Budget	Year	No. of Staff	Budget
1963	371	$3,225,642	1974	343	$ 6,503,782
1964	367	$3,513,953	1975	355	$10,524,305
1965	371	$3,410,353	1976	354	$10,549,968
1966	387	$3,680,723	1977	356	$14,471,259
1967	383	$4,759,815	1978	350	$11,985,502
1968	372	$4,328,956	1979	343	$17,586,866
1969	362	$4,255,142	1980	355	$10,353,050
1970	353	$5,220,609	1981	353	$11,884,101
1971	344	$5,788,267	1982	347	$13,879,655
1972	366	$7,774,135	1983	347	$23,551,769
1973	362	$8,600,420			

To compliment the technical assistance, the Agricultural Stabilization and Conservation Service began providing cost-share money for soil conservation practices in 1933. Table Two details the annual appropriations coming to Illinois from this funding source.

TABLE TWO

Agricultural Stabilization and Conservation Service
Cost-Share Money
($1,000)

Year	Amount	Year	Amount	Year	Amount
1936	$ 2,629	1952	$9,139	1968	$8,413
1937	$ 2,013	1953	$7,836	1969	$7,135
1938	$ 1,957	1954	$4,260	1970	$7,278
1939	$ 3,446	1955	$6,568	1971	$5,879
1940	$ 3,447	1956	$8,598	1972	$7,429
1941	$ 4,039	1957	$8,189	1973	$7,364
1942	$ 7,374	1958	$9,418	1974	$2,759
1943	$ 9,255	1959	$8,251	1975	$4,515
1944	$12,455	1960	$9,106	1976	$4,142
1945	$10,739	1961	$9,669	1977	$4,958

Year	Amount	Year	Amount	Year	Amount
1946	$12,257	1962	$9,730	1978	$5,762
1947	$10,693	1963	$8,855	1979	$9,903
1948	$ 5,545	1964	$8,588	1980	$7,038
1949	$10,005	1965	$8,550	1981	$7,291
1950	$10,684	1966	$8,596	1982	$6,375
1951	$20,388	1967	$8,878		

While the technical assistance and cost-sharing programs have continued in the same basic format in which they were created, there have been substantial changes in emphasis. Much of the early technical assistance and funding was directed at agricultural production practices such as liming of fields, tile drainage, and clearing of wood lots. In more recent years, particularly since 1972 after the adoption of the Federal Water Pollution Control Act, the emphasis has been on improvement of water quality, maintaining the productive capability of the soil, and targeting the conservation programs on a worst first basis. Recent general accounting office studies have been critical of the federal conservation program because a large percentage of the manpower and financial resources of the USDA programs were directed at production practices which the farmer could install by himself and on land that already met acceptable soil loss tolerances. Illinois has been a leader in changing the emphasis of the program away from production practices. It was one of the first states to stop funding subsurface drainage and limestone and one of the first to place an emphasis on water quality improvements and off-site benefits from erosion control.

The state of Illinois was involved very early in assisting soil and water conservation districts in their establishment. The University of Illinois College of Agriculture provided organizational and legal assistance to districts and played a major role in the relatively rapid blanketing of the state with soil and water conservation districts. The Illinois Department of Agriculture in later years provided management and financial assistance to soil and water conservation districts. Table Three provides information on the financial contribution of the Illinois Department of Agriculture to soil and water conservation districts.

TABLE THREE

State Funding From Illinois Department of Agriculture
for Soil Conservation Department Operations
and SWCD Grants

Fiscal Year	Operations	Grants	Total
1969	$120,275	$ 332,500	$ 452,500
1970	$103,384	$ 290,000	$ 393,384
1971	$118,500	$ 355,200	$ 473,700
1972	$107,200	$ 362,900	$ 470,100

Fiscal Year	Operations	Grants	Total
1973	$ 96,300	$ 502,900	$ 599,200
1974	$105,300	$ 502,900	$ 608,200
1975	$116,000	$ 522,000	$ 638,000
1976	$117,000	$ 526,000	$ 643,000
1977	$118,000	$ 488,700	$ 606,700
1978	$128,000	$ 488,700	$ 616,700
1979	$125,000	$ 488,700	$ 613,700
1980*	$144,000	$ 988,700	$1,132,700
1981	$563,700	$2,323,700	$2,887,400
1982	$536,700	$1,833,000	$2,369,700
1983	$535,700	$1,978,800	$2,514,500
1984	$519,740	$2,278,800	$2,798,540

*Creation of the Division of Natural Resources

In early years the funding was to provide secretarial assistance to the districts and the Soil Conservation Service. In later years, these grant monies have been used to provide staffing for technical assistance for district programs. The state has also began to fund modern soil surveys at one fourth of their total cost. This reduces the local cost to one fourth with SCS funding one half of the survey. County governments have also provided much needed funding to districts. Table four provides information on county contributions to districts.

TABLE FOUR

County Board Appropriations To Districts

Fiscal Year	Appropriations	Fiscal Year	Appropriations
1975	$140,603	1980	$371,369
1976	$190,058	1981	$378,376
1977	$218,170	1982	$475,251
1978	$282,406	1983	$483,751
1979	$327,387		

Recently the city governments of Taylorville and Springfield have provided funding to districts for the purpose of purchasing reduced tillage equipment to work in the watersheds of the lakes from which they receive their water supply.

The Illinois Department of Agriculture has provided staff assistance to soil and water conservation districts in varying degrees over the years. Two important functions which they have always carried out is to assist in the election of directors and to administer the grant monies going to the

districts. Since 1980 when the Division of Natural Resources was created, the scope of services provided to districts has expanded to include assistance in mine reclamation activities, farmland protection, water resources as well as soil conservation programs. As you can see from Table Three, funding to soil and water conservation districts has increased substantially since 1980; however, it has not increased at the rate projected in the 208 Water Quality Plan.

The demand on districts for services to their urban and rural constituents has increased substantially with the passage of the Erosion and Sediment Control Program, the Farmland Preservation Act, Natural Resource Opinion Reviews authorized by Section 22.02A of the District Act and the advent of the Surface Mine Reclamation Program in which many districts participate. Two new laws were passed this year - Senate Bill 1348 "Water Use Act of 1983 and Senate Bill 1036 "Illinois Forestry Development Act". In the last ten years district programs have expanded tremendously and I believe they will expand substantially more in the next decade. It is clear that Soil and Water Conservation Districts are establishing themselves as the natural resource agency at the county level. The 98 districts in Illinois provide a tremendous amount of service, mostly free, in a large variety of resource areas to the citizens of Illinois. I believe their role will continue to increase as more responsibilities are placed upon them and as they meet those responsibilities in a professional manner.

After completion of the 208 Water Quality Plan dealing with agriculture in the late 70's, the United States Environmental Protection Agency seemed to lose interest in the agriculture non-point source pollution program. That interest has again been rekindled with resolutions and bills being introduced in Congress to amend the Clean Water Act (H.R. 4037 and S. 431) by Representative James Oberston (D-MN). Senate Bill 431 provides for grants to states to deal with implementation programs for agriculture non point sources of pollution. There is an expectation that some of this funding will be passed through to soil and water conservation districts to hire technical employees to work with land owners on the installation of best management practices. The United States Department of Agriculture is also planning to initiate a grants to districts program in the 1985 federal budget year. The so-called Sod-Buster Bill (S. 663) has passed out of the Senate Agricultural Committee. This bill, and other proposals like it, would withhold USDA programs from land owners who plow fragile lands. Other federal proposals would provide long term funding for contractual arrangements to remove highly erodible land from production. It is my expectation that cross compliance will also be a major discussion item along with the Sod Buster Bill and long term conservation contracts when the 85 Farm Bill begins debate in Congress. Some members of the Senate have pushed for stronger agriculture non point source pollution programs, it doesn't appear likely that those will pass at this time. However, the trend is certainly to withhold USDA programs from those who do not properly manage their land and to provide some funding for soil and water conservation districts to hire their own technical employees. Soil conservation and non point source water pollution programs are destined to be with us in future USDA and USEPA grant and regulatory programs.

From its humble beginning in the mid 30's, the national and state soil conservation programs have made great strides but they have not progressed far enough or fast enough. I certainly would not characterize the financial, technical, and moral commitments to this program in Illinois as too little, too late. However, I point out that the federal funding levels have either declined or remained static. The state funding has increased rather dramatically since 1980 but it is not yet to a rate that it was projected to be in the 208 Water Quality Plan. The field work on soil surveys that was originally scheduled to have been completed by 1991 continues to fall further behind.

Conservation tillage and zero-tillage provide the only realistic hope that we have for meeting our goal of "T" by 2000. Of course, other management practices are required to compliment the reduced tillage systems, but conservation tillage alone can control erosion to tolerable losses on over half of our 10 million acres of eroding crop land.

Some have suggested that "T" by 2000 is an unrealistic goal. I disagree with this. I believe that it can and must be met. I am sure the citizens of Illinois will not tolerate farming practices which continue to allow our soils productive capacity to be degraded and our water quality and water resources to be degraded by off-site sediment damages. These difficult challenges can and must be met if we all work together aggressively and diligently. The 97 percent of the population that do not live on farms must be made aware of their continuing obligation to assist land owners in installing expensive enduring erosion control measures and our farmers must realize that all conservation practices are not going to be cost-shared with tax dollars. There is an obligation for the farmer to practice reduced tillage methods and install other cost effective conservation management practices on their own.

When the conservation needs inventory information is released later this year and we can compare the total soil loss in Illinois to the 1977 figure of 188 million tons, we will then know if we have done enough in the past five years, and whether we are on track in meeting our erosion control goals. If we are not, we must redouble our efforts, we all must try new approaches and work more closely together - state, federal and local agencies, farm organizations, environmental groups, private citizens, and farmers.

Fellow friends in conservation, we must declare the moral equivalent of war against these problems and we must commit more public and private resources toward solutions. There will be those that do not have agriculture's best interest at heart who will say "T" by 2000 is an unattainable goal and besides there are other public priorities more pressing. There will be those who say that water quality improvement will have to wait. That the preservation of our prime farmland from unnecessary conversion must take a back seat to economic development or that we must lower our soil reclamation standards for strip mining in order to extract coal more cheaply. Well, I ask those people what will it cost our children and grandchildren if we do

not manage our natural resource base responsibly now. It will cost far more in the future. The time to act is now. We are at a crossroads in natural resource management programs in Illinois. We cannot go backwards. We cannot slow down. We must charge ahead aggressively even if it means stepping on some toes or rocking some boats for it is only by rocking those boats that we can make clearer waves and as we collectively continue this battle. Let us never use phrases such as muddy the water, cheap as dirt, or losing ground. Thank you.

ILLINOIS EROSION CONTROL PROGRAM: AN ENVIRONMENTAL PERSPECTIVE

Ken Mitchell, Executive Director
Illinois Environmental Council

Environmentalists are badly misunderstood especially by farmers like yourselves.

We are perceived as urban do-gooders with hearts instead of brains by people with enough money and security to have the luxury of criticizing business, industry, farmers, and almost everyone else under the misguided guise of public interest. Environmentalists are seen by many as malcontents who could not be shut up even if there was no pollution. They are a product of the discontentment of the sixties, it is often felt. Young discontents that have grown older and bitter and louder and more offensive.

I come to you today to do two things. First to dispel this untrue caricature of environmentalists and offer for your consideration a truer image. And secondly, I come to you this morning to give some environmental thoughts on soil erosion.

It is my view as a one-time farmer, one-time landowner, one-time biologist, and present administrator and lobbyist for the Illinois Environmental Council (IEC), that environmentalists are worth having...and more.

"Environmentalists" is obviously a poor name, isn't it? For as my farm friends keep reminding me, they consider themselves environmentalists, too. I admit labels <u>are</u> problems, but to call one person an environmentalist is not necessarily to say another is not. For example, in the IEC sponsored project COMMON GROUND, we have brought together farm interests, environmental interests, and conservation interests to sit down for a two-year period and discuss important mutual issues such as soil erosion, natural areas and pollution. Right from the start we made it clear that many farmers consider themselves environmentalists just like some environmentalists are farmers. So please never think environmentalists feel they have proprietary rights with the term "environmentalist". It causes more problems for me than almost anything else.

Well, it is my view that environmentalists are people too. They are concerned about what kind of environment we leave to our children; they are concerned about treating it with a kind of parental care because they have discovered (like most of us) that we are injuring our world in ways that threaten irreparable harm. Sometimes they over react: sometimes they are flat-out wrong; but in most cases, they have proper concerns in proper proportions. They would say to the manufacturers who pump more than one-half of all the hazardous waste produced in Illinois into 5,000 foot deep well injection systems that it is wrong and dumb to do so because the potential harm we can't yet describe or know far outweighs the short-term benefit of getting it out of our sight.

Environmentalists are saying - as I did recently in the legislature - it is better to err on the side of reason. That makes sense to me and it should make sense to you since rural areas are the principal dumping grounds...but it did not make sense to most of the state senators and representatives.

All I am saying about environmentalists and the main thing I want you to consider is that environmentalists like yourselves are people who care, and care deeply enough to be active about doing something. That is why we have an IEC - the only full-time environmental lobbying group in Illinois.

These people are not silly, they are saying serious things and helping people to think differently about their world - that we can no longer pollute and discard things because science and common sense have recently taught us that we are likely to kill ourselves in the process, or at the least make life much harder on all of us. Enough said about environmentalists.

A few remarks about soil erosion. You all know much more about the subject than I do. All I want to say is how our organization and other environmental groups belonging to IEC feel about it. Here are a few statements from the eyes of environmentalists that you need to hear.

Environmentalists stand between your progress on soil erosion and the public. Like it or not, we are in the public's eyes the interpreter, the reporters as to how well you are doing. Because of this, we are important to you as is the state legislature, the state agencies and the governor.

It is, therefore, important that environmentalists have a role in the soil erosion battle. Farm groups have worked well with environmentalists in what we are all considering a mutual battle. There is no need to have anything but cooperativeness because the soil erosion battle needs all of us and the public as well.

It is, therefore, in your best interest to have outside pressure exerted on the soil erosion program - pressure to do more, and do it better and faster.

So all such forums such as this one and Common Ground are vital in keeping the soil erosion issue in front of the public.

A few words about the environmentalists' philosophy about soil erosion. Our country was built on soil, our economy is built on soil, Illinois is built on the soil, our future is especially built on soil, and the world's future in built on soil - our soil. It must be protected at all costs and that includes economic incentives to farmers. It is irreplaceable and limited.

It is the natural resource and Illinois' number one business. We have not been the stewards we should have been. It is familiarity breeding contempt. It is the story of what is given freely is often freely abused. The time has come to stop that abuse and that is your reason for being here today and the last several years. It is a race against time, in our opinion, because every

day farmers, absentee owners, corporate farmers, cash renters, and the public allow this natural resource (more precious than gold) to go into rivers, into the air, and in the process damage our precious water quality.

I see the environmentalists' role as assisting you, and at times pushing you, toward winning this race. Whether we know it or not - and whether we like it or not - my friends and fellow farmers, all eyes are on us and you in this effort. Future historians will judge later what you do now. For we are major actors in what will someday be recorded as one of history's major plays.

Let us play it right...together. Let us make it a historic success not a tragedy. Good luck and thank you.

COST EFFECTIVENESS OF CONSERVATION PRACTICES

Frank H. Schoone, ACP Program Specialist
Illinois Agricultural Stabilization and Conservation Services

Recognizing the growing pressures on the resources that produce food and fiber and the need to improve the effectiveness of soil and water conservation efforts, congress enacted the Soil and Water Resources Conservation Act of 1977 (RCA). The Act directed the Secretary of Agriculture to appraise the soil, water, and related resources of the nation.

The Act further directed that programs administered by the Secretary of Agriculture for the conservation of soil, water, and related resources be responsive to the long-term needs of the nation, as determined by the appraisal. It required the secretary to:

1. Develop and update periodically a national program for conserving, protecting, and improving soil, water, and related resources consistent with the roles and responsibilities of other federal agencies and state and local governments.

2. Provide congress and the public with the appraisal and program report.

3. Provide congress with an annual evaluation report.

During fiscal year 1977, the Agricultural Stabilization and Conservation Service (ASCS), at the request of the president, undertook an evaluation of the Agricultural Conservation Program (ACP). The evaluation design included two phases. Phase 1 was carried out through an inter-agency evaluation team operating under the auspices of the Under Secretary for International Affairs and Commodity Programs, the Assistant Secretary for Natural Resources and Environment, and the Director of Economics, Policy Analysis and Budget. That phase was based on a 5 percent sample of all counties involved in the ACP. Estimates of the reduction of soil loss due to sheet and rill erosion and estimates of the amount of water conserved as a result of the application of conservation practices were provided by the Soil Conservation Service (SCS). The Forest Service (FS) provided evaluation data for the forestry practices.

ASCS collected information from 171 counties. ACP practices applied in the sample counties from 1975 through the first half of the 1978 program year were included in the study. ASCS reviewed 60,836 cases. Each case represented a practice for which a farmer received cost-share assistance. The Universal soil loss equation was used to estimate the erosion reduction achieved. The evaluation showed a number of areas in which cost-effectiveness could be improved, particularly with respect to erosion control practices.

Some findings of phase 1 of the evaluation included:

1. Most ACP practices do reduce soil erosion and conserve water, but the costs of installing the practices and the results achieved vary considerably by region of the United States and within each region.

2. ACP Cost-sharing has resulted in sheet and rill erosion reduction of about 41 million tons per year, about 1.5 percent of all erosion on cropland estimated for 1977.

ASCS provided the evaluation results to agency officials and to state and county ASC committees for guidance in program development.

In response to the Soil and Water Resources Conservation Act of 1977, USDA prepared the National Program Report for Soil and Water Conservation. The report presented the programs that the Department developed in response to the Act and was formally presented to congress by President Reagan in December of 1982.

The report discussed and identified resource problems, analyzed the effectiveness of existing programs, established the objectives of a national program, and presented procedures under which the new program would be evaluated. Throughout the report the strengths and weaknesses of present programs were evaluated and a need for a comprehensive conservation effort by USDA was identified.

The previous ACP evaluation collected a limited amount of data, such as; farm size, farm type, land class, T-value and soil loss. Experience showed that the information collected was of great value in analyzing program results but left many questions unanswered. Other USDA agencies which assisted ASCS saw the value of the resulting data and were interested in participating in a broadened evaluation effort. The need for more evaluation data to increase knowledge relating to program performance and interest of other agencies provided the basis for a Conservation Reporting and Evaluation System (CRES).

CRES was developed by ASCS and SCS in consultation with Forestry Service (FS), Economic Research Service (ERS), Extension Service (ES), and Agriculture Research Service (ARS), to meet certain program management and evaluation needs. The system provides for the collection, storage, retrieval and analysis of cost and effects data associated with the application of conservation practices and systems. It is designed to permit the collection and use of data needed to manage county and state conservation programs as well as the national conservation program.

ASCS and SCS have, at the national level, entered into a memorandum of understanding which establishes a cooperative working relationship between the agencies for carrying out the Conservation Reporting and Evaluation System. It was agreed that ASCS would provide all necessary services for CRES associated with the form design, development of computer programs, and the data entry into the USDA computer located in Kansas City, Missouri. Both ASCS and SCS have concurred with the "form" to be used for the collection of

data and the operating instructions. A form called "AD-862" is the name of the collection form developed by ASCS and SCS for the CRES system. Authorized personnel from each agency will have full and unrestricted access to the data collected.

Data collection for the interim CRES began in October 1982 and the ACP evaluation was discontinued at that time. By January of 1983, some 1,000 counties were included in the interim CRES and data was being recorded for the Agricultural Conservation Program (ACP), Rural Clean Water Program (RCWP), Great Plains Conservation Program (GPCP), and for SCS Conservation Technical Assistance (CTA).

Data collected under the CRES can be used to evaluate the major areas for which benefits are realized from installation of conservation practices, i.e., (1) soil saved, (2) water conserved, (3) animal waste, (4) wood production, (5) forage production, (6) salinity, pesticide and fertilizer control, and (7) drainage improvement. Additional data is also being recorded such as: farm and soil characteristics, cost of practice applications, irrigation activities, wildlife habitat diversity, and technical assistance.

Interim CRES has been so successful that as of October 1, 1983, all ACP states and counties have been included in CRES and other cost-share programs are also covered, namely; emergency conservation program, water bank program, forestry incentives program, PL-566, RC&D, and possibly others.

CRES is now recognized as an interdepartmental system to collect, store, retrieve, and analyze data for all land treatment conservation programs administered by the USDA.

SCS has agreed to provide technical data for all cost-shared practices that ASCS refers to them for technical assistance. It has also been agreed that SCS will provide erosion and water conservation technical data or train ASCS personnel for those cost-share conservation practices which are not referred to them for technical assistance.

All "before" and "after" installation data pertinent to a cost-shared practice will be entered on the form AD-862 when the practice needs and feasibility are determined.

This data will provide our local ASCS committees with site specific data for comparison purposes before committing resources or expending funds. This should increase the treatment in priority problem areas as well as get the most conservation for each dollar spent.

CRES provides program managers at all levels the ability to compare conservation practices/systems and programs for cost-effectiveness. This joint and comprehensive effort requires better communication, more coordination, and a higher degree of consistency among agencies of USDA at

all levels and strengthens their conservation partnership. But best of all, program effectiveness is being improved by program managers at all levels because of the availability and confidence in the site specific data in CRES.

As of October 1, this year, CRES will record both evaluation and statistical data for all states and counties and will interface with other systems. This will eliminate the need for a separate conservation reporting system. CRES is expected to provide a single system capable of recording data for most USDA, natural resource programs.

The system will be invaluable in providing information to OMB, GAO, and congress while providing counties, states and national administrators with improved knowledge for administering the programs to ensure the most efficient use of each dollar expended.

IMPACT OF SOIL CONSERVATION PROGRAMS ON SMALL STREAMS

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Soil conservation as a philosophy and program grew out of the dustbowl of the 1930's. More recently, a resurgence of interest and concern for the problem of soil conservation developed as a result of the dual concerns: present rates of soil erosion endanger long-term food production capabilities and water quality degradation is a major threat to society. Although not the sole contributor to degradation in the quality of water resources, agriculture, either directly or indirectly, impacts the largest portion of midwestern streams. To the extent that soil erosion contributes to these dual problems, effective soil conservation will benefit society.

My goal today is not to complete a comprehensive review of the impacts of soil conservation programs on water quality. That would be impossible in the time available. Rather, I will make 11 statements relevant to the impacts of soil erosion on water resources. Each of those statements will then be documented while I argue for their consideration to insure the greatest societal benefit for water resources as a result of soil conservation programs. Although my comments will be restricted to consideration of soil conservation impacts on streams and rivers, most of the principles apply to effects of soil erosion and its control on lakes, ponds, and reservoirs.

1. Impacts of agriculture on water resources have been largely negative during the past century. Human population increases combined with technological impacts have been instrumental in degradation of water resources. The complex interactions that have resulted in water resource degradation are illustrated by perturbations stemming from historical changes in agricultural ecology (Cox and Atkins 1979). The conversion to intensive agriculture has been particularly important in changing running water resources in the Midwest; indeed, it was probably the first major encroachment on inland waters (Cairns 1978).

Early settlers were limited, for the most part, to raising livestock and small plots of crops on naturally well-drained land that could be cleared of trees or prairie grasses (Larimore and Smith 1963). With the development of improved farming techniques and equipment (e.g., the steel plow), more land was cleared and fields expanded. Ditches were dug by individual farmers to drain marshy areas. Crop rotation, fallow land, and manure were used to replenish soil nutrients removed by crops and erosion.

In Illinois, the Farm Drainage Act of 1879 promoted the formation of drainage districts that allowed farmers to work together on drainage projects covering large areas (Larimore and Smith 1963). By 1920, 70 percent of the Illinois

counties studied by Larimore and Smith had undergone drainage improvements. Bottomlands along rivers and streams were cleared of trees, ditches were dug, and underground tiles installed to lower the water table and accelerate groundwater flow to natural streams. In some places tiles resulted in burying what were originally surface water courses (Larimore and Smith 1963). Dredging and straightening of existing streams also increased the rate of drainage. Drainage impacts combined with environmental modifications associated with the initial tilling and draining of the prairie in the early 1800's had dramatic effects on stream environments. By the late 1800's many streams that were originally deep, narrow and of continuous clear, cool flow had become wide, shallow and widely fluctuating in discharge as a result of changing land-use (Menzel and Fierstine 1976). In fact, changes in water flow regimes in streams combined with modifications of soil structure (resulting from clearing and cultivation) altered the dynamics of the entire watershed.

Overall, the development of legal (Farm Drainage Act of 1879), institutional (soil and water conservation districts), and technological (farm implements, pesticides, fertilizer) innovations speeded the shift to more intensive cultivation. Vigorous hybrids and improved varieties along with the use of herbicides and pesticides have, by increasing production, also led to reduced concern about natural soil fertility. "Soil-building" crop rotations have been abandoned in most areas and replaced by high-income crops that deplete nutrients in one year rather than over the course of a multiyear crop rotation (USDA 1981). Wheat, corn, and later, soybeans became the leading crops because they were marketable on a large scale.

With agriculture depending less, in the short-term, on natural fertility for sustained yields, and growing world markets in the 1970's, even marginal and poor lands were being cleared and cultivated. Farmers now more than ever put every available acre into production, often resulting in abandonment of conservation practices (Karr 1981) and accelerated erosion rates.

In fact, erosion has once again become a serious problem. While the technology of agriculture has changed tremendously since the 1930's, the administration of Federal erosion-control programs continues to be carried out in much the same context as it was during the Depression, especially in terms of short-term, benefit/cost relations to the farmer, the landowner, and society at large (USDA 1981, Karr 1981). In 1979, Rupert Cutler, then assistant to the Secretary of Agriculture, made the observation that "after 40 years of conservation efforts, soil erosion in now worse than during the Dust Bowl days" (Risser 1981). Rain and melting snow continue to wash tons of soil from fields. Much of that soil ends up in streams, rivers, and lakes, impeding the flow of water and destroying essential habitat for fish and other wildlife. In addition to sediment, livestock waste and chemical pollutants (nutrients, herbicides, and pesticides) carried by the soil also find their way into water systems.

With sediments from erosion clogging stream channels, dredging and rechannelization efforts have increased. Perpetual channelization of large rivers is also necessary to keep channels open for navigation. Part of the demand for navigable rivers lies in the need for barges to move grain and other products cheaply to ports. Thus, agriculture-related impacts, including drainage, erosion and sedimentation, nutrient enrichment, pesticide runoff, and altered hydrology, have clearly had a profound effect on water resources in streams and rivers.

Along the continuum from headwater streams to large rivers relative impacts of various perturbations change. Modifications due to agriculture seem to have their greatest direct effect on headwater streams. In addition to being subject to extensive channelization and removal of near-stream vegetation, headwater areas are the primary sites of sediment inputs from the land surface (Karr and Schlosser 1978). Since these areas are important spawning and nursery grounds for commercial and sport fish that spend their adult life in lakes or large rivers (Karr and Gorman 1975), modifications of headwater streams have wide-ranging as well as local impacts.

Watershed and stream channel alterations have resulted in degradation in both physico-chemical attributes of water as well as declines in biotic integrity. In the aggregate these have negatively impacted in the quality of water resources. Analysis of the fishes of the Illinois River and its tributaries shows that fully 66 percent of the 131 species known from the watershed have declined in abundance or disappeared from the watershed since 1850 (Karr et. al. 1981). Small headwater streams are most significant in miles of streams and in the most directly impacted by agriculture; 64 percent of species have declined or disappeared from these small streams.

<u>Overall, these comments clearly show the need for programs to reduce the negative impacts of agriculture on the quality of water resources whether they impact the integrity of the stream biota or man's use of water for industrial, domestic, or recreational purposes.</u>

2. <u>Societal activities other than agriculture have had a profound impact on water resource quality</u>. Urbanization, industrial development, navigation, hydroelectric development, and recreation have all had significant impacts on the quality of water resources. Impacts of modifications such as dredging and dam construction are obvious, while others are more indirect. Urbanization, for example, alters watershed hydrology and thus disrupts flow dynamics and channel equilibrium. Maintenance of navigation channels has had a profound impact on large rivers through creation of lock and dam systems and flood control programs have altered the water resources of both large and medium sized rivers. Medium sized rivers in the Illinois River watershed have lost or experienced reduced populations in 75 percent of species while 58 percent of species have been so affected in large rivers. The impacts of nonagricultural activities of human society are especially great in the large rivers due to navigation and the sewage diversion from Chicago. In the Maumee River of Ohio and Indiana where urban and industrial impacts are less

than in the Illinois River, only 23 percent of species have declined or disappeared. For fish as well as for other metrics used to evaluate water resource degradation, improvement of agricultural practice (including soil erosion control) will not solve all water resource problems.

3. Since many agricultural and nonagricultural activities negatively impact water resources, problems with degradation of those resources cannot be resolved solely through programs designed to reduce soil erosion. Following passage of PL 92-500 a flurry of activities developed to improve the quality of water resources. Point sources were treated first with a latter focus developing on non-point sources, most of which originate from agricultural lands. These programs were not successful because they were based on inadequate premises. One of the longest running such projects was the Black Creek Project, in Allen County, Indiana. That project, like most others initiated since 1973, began with the assumption that an effective program of soil conservation would result in high-quality water resources. A secondary assumption was that every acre of agricultural land in the watershed must be treated to achieve goals of soil conservation as well as to solve water resource problems. Within a few years the inadequacies of those assumptions became obvious to most project participants. Yet, even today those same assumptions and goals persist in many projects.

An extensive list of practices acceptable to reduce soil erosion was used without critical evaluation of the impact of each practice on water quality. Within a few years it became clear that a number of practices did not improve the condition of water resources and many, in fact, had negative impacts of water quality. For example, a desilting basin was installed in the main channel of Black Creek to reduce downstream sediment transport and, thus, improve water quality downstream. During low flows throughout most of the year, total residue increased by eight percent while total phosphorus and turbidity increased by 58 percent and 41 percent, respectively, as water transited the desilting basin. Overall, project participants concluded that this and several other practices thought to reduce the impact of soil erosion on water resources actually had the reverse impact. As a result of such impacts on water quality, the concept of Best Management Practice for improvement of water resources was developed because only a subset of classical SCS conservation practices actually function to improve water resources.

4. Solution of water resource problems in agricultural watersheds must treat problems associated with declining biotic integrity as well as degradation in physical and chemical attributes of water. The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) set forth the objective of restoring and maintaining the "...chemical, physical and biological integrity of the Nation's waters..." As a result, many efforts to improve water resources were generated, but most concentrated on criteria and standards for specific contaminants, usually based on 96-hour acute toxicity tests on a few standard organisms. This narrow focus developed because of ambiguities in early water resource legislation despite inclusion of the biotic integrity

goal. With passage of the Clean Water Act of 1977 (P.L. 92-217), a more comprehensive definition of pollution came into existence. Despite this refinement, regulatory agencies have been slow to replace the classical approach (uniform standards focussing on contaminant levels) with a more sophisticated and environmentally sound approach.

The reasons for this problem are diverse but a key problem has been the background of water resource planners. They often lacked the interdisciplinary perspective to consider the full array of ecosystem functions and needs. Their primary target was restoration of the chemical quality of water; desirable biological quality, it was assumed, would follow. In most cases, streams were viewed only as conduits for the transport of water. The fundamental biological nature of aquatic systems and their complex interrelationships with terrestrial watersheds frequently went unrecognized. As a result, biotic integrity continued to be degraded, and improvement from affluent control was minimized.

A multivariate complex of factors determines the integrity of a water resource system (Figure 1). The attributes of a running water ecosystem are ultimately determined by characteristics of the terrestrial environment. The physical structure of stream channels and their flow reflect climate as well as topography, parent material, and land-use in the basin. These factors interact to produce surface and groundwater dynamics. The riparian environment plays a major role in mitigating these influences at the land-water interface. Within the stream itself, five major sets of variables interact to affect biotic integrity: water quality, flow regime, physical habitat, energy source, and biotic interactions (Figure 2).

Historically, water resource planners have considered only water quality and, to a lesser extent, flow regime when analyzing streams and rivers. But a prerequisite for maintenance of biotic integrity is knowledge of biological and hydrological dynamics. Biologists should no more ignore the hydrological underpinnings of the stream ecosystem than should engineers and hydrologists ignore the ecosystem's biological foundations.

Several ongoing agricultural programs have been used to address water resource problems (e.g., SCS Conservation Farm Plans, Small Watershed PL 566 Plans, Rural Clean Water Program, etc.) but they have been largely ineffective in restoring biotic integrity because of a narrow planning horizon.

In agricultural areas the following 6 problems require careful treatment and improvement if biotic integrity is to be restored:

1. Organic matter inputs: Organic input from sewage and stormwater runoff is substantial as evidenced by high bacterial contamination. This results in major structural and functional changes in stream ecosystems.

2. Nutrient availability: Concentrations of simple nutrient forms are high.

3. Sunlight availability: A predominance of unshaded stream channels results in high solar energy input. When this is coupled with nutrient availability, algal populations increase. These populations are subject to either slow decay in the headwaters or mass washing downstream during highflows. These algal blooms add to the organic load of the aquatic system and change the physical characteristics of the stream environment (reducing current velocities, covering natural substrates, etc.).

4. Temperature and dissolved oxygen imbalance: Seasonal and daily patterns of temperature and dissolved oxygen are exaggerated and poorly buffered from environmental influences.

5. Stream habitat characteristics: The diversity and stability of high quality stream habitat is low. Ditching and drainage efforts prevalent in some agricultural watersheds perpetuate this problem.

6. Seasonal low flows: The loss of natural vegetation and installation of complex drainage networks results in rapid runoff instead of slow release of excess water. As a result, extreme low flows during dry periods, especially in late summer and early fall, place considerable stress on aquatic ecosystems.

Selection of conservation practices must involve plans to alleviate all of these problems if water resource degradation is to be reduced. Further, special care should be taken to prevent selection of conservation practices that are only production and/or drainage oriented. For example, less than half of the money allocated to ASCS to foster conservation of soil and water resources was used for measures primarily oriented toward conserving the nations topsoil; most went to improve crop yields (U.S. General Accounting Office 1977 Karr 1981). When costs of activities that have little direct relevance to improvement of water resources are included in efforts to estimate non-point source control costs, total costs for water quality improvement are grossly inflated.

<u>Adequate approaches to these complex problems must protect biotic integrity and other attributes of water resources as well as serve the interests of soil conservation</u>.

5. <u>Conservation programs, to be effective for protection of soil and water resources, must be based on innovative, conceptually broad, and highly integrated Best Management Systems</u>. Soil conservation practices (BMPs) applied to the land may have water quality benefits but they are only a portion of the system of practices required for sound management of water resources. Thus, the time is right for a careful application of an extended list of BMPs for water quality improvement. These must be tailored into integrative Best Management Systems suited specifically to each watershed.

The following questions must be routinely asked: What will be the effect of juxtaposition of several practices? How will they affect the widest range of water resource characteristics, not just how will they affect erosion control on the land, or water quality? What are the impacts of these practices on biological integrity?

As noted above, this does not imply the extraordinary sums of money often quoted necessary to improve water resources. Indeed, reduced cost for treatment of soil erosion and reduction in negative impact on agricultural production will often result from careful, integrated management efforts.

Only two such approaches will be mentioned here. First, planners should learn from the inadequacies of early programs, such as the Black Creek study where initial goals included treatment of every acre of land with every soil conservation practice which would reasonably be expected to improve water quality. Later, emphasis was correctly placed on identification of highly erosive areas and their treatment. Thus, at relatively low cost acres with the greatest impact on water resources could be corrected.

Second, man alters streams by dredging new channels in poorly-drained areas or by modifying existing natural channels. These man-engineered watercourses must be considered streams even though they are clearly different from natural streams in many respects (for example, drainage and flow characteristics, chemical and physical conditions, bottom type). Important as these differences are, one basic ecological principle applies to both man-altered and natural streams; water, nutrients, and energy are exported to downstream areas. Thus, man's construction of drainage ditches is not separate from natural drainage patterns; rather, it is only an addition to or a modification of the natural stream network that profoundly affects water resources both locally and downstream.

Application of best management practices, outside the framework of integrated planning efforts, may have little measurable impact (or even negative impact) on nonpoint source pollution.

6. In design of integrated land treatment programs, care should be taken to use the natural buffering capacity of riparian environments and associated streams. By careful design of land treatment programs, it is possible to utilize the filtering potential of green belts of vegetation along streams. Structurally diverse natural streams typically have a great deal of buffering capacity: meanders tend to moderate the effect of floods, pools offer excellent refuges for fish during dry periods, tree shade decreases heat loads minimizing the oxygen-robbing effects of decomposition and extensive algal blooms, trees provide energy sources for the stream biota in the form of leaves, and benthic invertebrates help to filter organic particulates from the water column and sediments. This has been demonstrated by numerous field studies and consideration of the dynamics of sediment transport in the presence of complex biological systems. These biological systems function in much the same way as secondary treatment of sewage. If natural buffering

capacities are not exceeded, they will provide considerable benefit at little cost.

7. Land treatment programs should involve careful evaluation of nonstructural as well as structural alternatives. Structural alternatives are both expensive to install and to maintain. In addition they have periodic, high maintenance costs that are often coupled with other major impacts on water resources. Finally, implementation of many structural practices and associated construction activities (initially and during repairs) often create instabilities in near-stream and channel environments that may produce more sediment movement than a no action alternative. An example of that in Black Creek on the Wertz Drain resulted in destruction of an area of high biotic integrity following efforts to "stabilize" upstream channels that really produce exceptionally high sediment loads.

In many cases, nonstructural alternatives might yield more water quality benefits at lower cost. Nonstructural alternatives such as altered tillage or altered rotations may prove to be economically attractive (for example in the face of rising energy costs) as well as useful to reduce soil erosion and water resource degradation.

8. Both the attainment of legislative mandates and preservation of soil and water resources for future generations requires a more careful stewardship of natural resources. While some alteration of soil and water resources may be unavoidable, careful planning can significantly reduce negative impacts and may even resolve problems with minimal impact on the economics of agriculture.

9. Specific soil conservation practices have varying relevance to the goal of improving the quality of water resources. Since each of the practices have varying utility depending on the larger management framework in which each is imbedded, I am reluctant to make specific recommendations for traditional practices. Further, truly integrative land management programs must incorporate a wider range of BMPs than the traditional practices associated with control of soil erosion. Several Black Creek project reports treat the merits of specific traditional practices while recent work sponsored by the Instream Flow Group of the U.S. Fish and Wildlife Service, Ft. Collins, Colorado is valuable in designing land management programs. The effects of removal of stream obstructions can be minimized by following recently developed guidelines (SRGC, 1983).

10. An integrative approach like the one outlined here can be expected to have a number of benefits to society. These include but are not limited to the following:

a. Improved water quality and quantity.
b. Improved integrity of the aquatic biota as well as for terrestrial wildlife associated with stream-edge (riparian) environments.

c. More effective and efficient processing of natural and man-induced organic inputs to running waters.
d. Spin off advantages to soil conservation.
e. Reduced sedimentation of channels and reservoirs from land and channel sources.
f. Decreased cost of channel construction and maintenance activities.
g. Reduced downstream flooding.
h. More intensive agriculture with reduced effects on aquatic ecosystems when land management systems are not feasible.
i. Increased recreational activities.
j. More cost effective attainment of legislative mandates for water resource systems.

11. More effective programs are both possible and practical. A more effective system is essential to avoid catastrophic declines in food and fiber production as well as irreparable degradation of land and water resources. A more enlightened program must be based on:

a. Sound knowledge of the dynamics of interacting soil and water resource systems.

b. Knowledge of the effects of human activities on these systems.

c. A governmentally-funded program of technical assistance to deliver this knowledge.

d. An array of incentive programs to insure selective application of that technical assistance where it is most needed.

e. A background of regulatory mechanisms that can be applied when voluntary and incentive programs are not successful.

12. The need for these programs is embodied in a quote from a Nigerian chieftain: I conceived that the land belongs to a vast family, of this family many are dead, few are living and countless members are still to be born.

In summary, I hope I have been successful in clarifying the impact of soil erosion program on water resources and streams. Those impacts are not always good. They can in the long-run be improved by planning efforts through a multidisciplinary team of well-trained water resource specialists. Maintenance of the status quo in soil erosion programs will do a disservice to the countless members of the human family that are still to be born.

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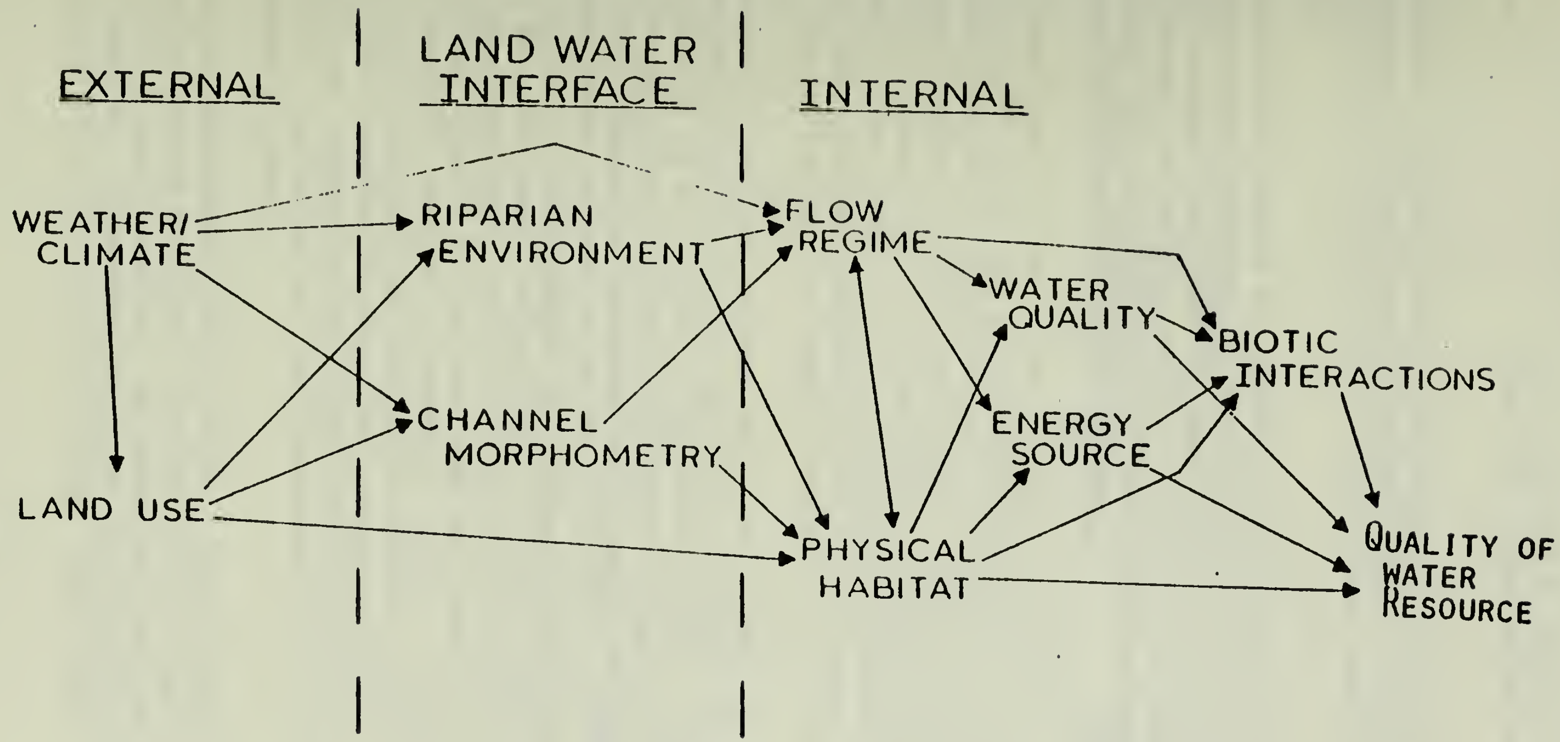

Figure 1. Conceptual model showing the primary variables (and their interaction) external and internal to the stream that govern the quality of a water resource system.

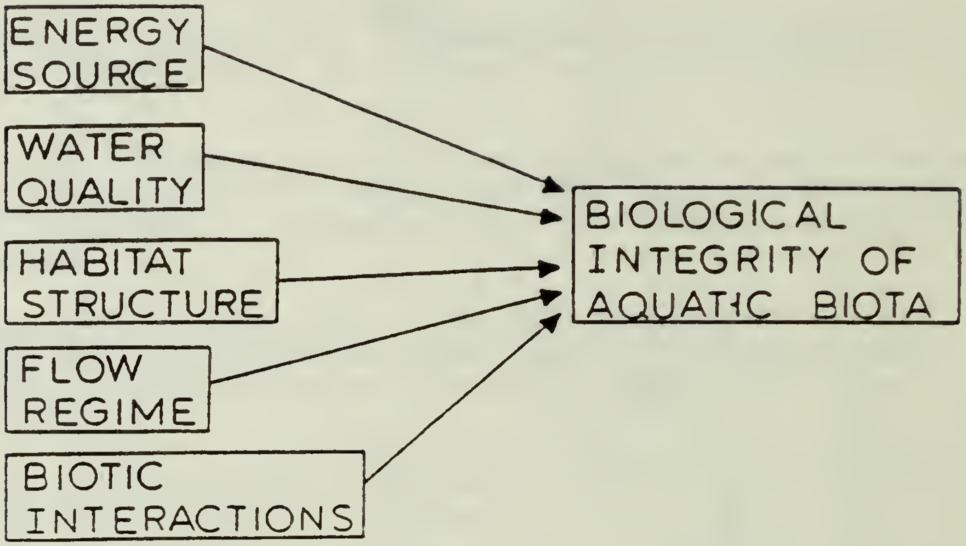

Figure 2. Primary variables that affect the structural and functional integrity of an aquatic biota.

SOLVING EROSION THROUGH RESOURCE MANAGEMENT SYSTEMS

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Illinois farmland loses approximately 106,000,000 tons of soil from erosion each year. Erosion occurs in many forms. Erosion is caused by sloping land, the length of slope, lack of cover on the land, and raindrops striking the soil.

The erosion problem in Illinois is complicated by the intensity of agriculture. Illinois is one of the leading producers of soybeans and corn. This intensive agriculture, while feeding millions of people worldwide, increases the erosion problem. Crops such as wheat and pasture cause less erosion than more intensively cultivated farm crops. Concentrated livestock also complicate the erosion problem.

Erosion comes in many forms, the most prevalent of erosion occuring in Illinois is sheet and rill erosion. Megarill or concentrated flow is another type of erosion. Gully erosion is a serious problem in many areas. Erosion causes on-site problems and produces many off-site problems in the form of sediment deposition and deteriorated water quality. Wind erosion is a problem that occurs on a more infrequent basis but yet very spectacular. This past year wind erosion caused severe damage to some land and contributed to several serious automobile accidents due to reduced visibility.

Because the erosion process is so complicated and the magnitude of the erosion problem so large, resource management systems are a necessity if erosion is to be reduced to tolerable limits. Many conservation practices can be installed to form viable resource management systems. Conservation tillage is a key component of any resource management system in Illinois. Conservation tillage can be chisel plowing, zero till, or ridge planting. Terraces are another important part of resource management systems. Terraces can be broad based, narrow ridge, or grass back. Tile outlet terraces release water at a slow rate, thus improving water quality as well as reducing erosion. Grass waterways and associated structures reduce gullying and megarill erosion to acceptable limits. Stripcropping can be another important component of resource management systems in certain locations. As with all conservation practices stripcropping has its limitations. A farmer must have the need or the market for forage for a successful stripcropping system. Contouring is a very inexpensive but important part of a resource management system.

Resource management systems not only reduce erosion but they also provide many associated benefits. Wildlife cover is provided by standing corn stubble. Grass waterways and grass back terraces provide cover and bedding for wildlife. Migrating waterfowl are provided resting areas and food by a complete resource management system. Small areas such as roadsides and

odd-shaped unformable corners of land can be managed as a part of a resourace management system to improve the overall wildlife condition of an area. Windbreaks and wildlife plantings are very important parts of a resource management system.

In summary, individual conservation practices will not solve a severe erosion problem or provide secondary benefits. Practices can be combined to form a resource management system to reduce the various types of erosion to acceptable limits. The type of farming operation and interests of the farmer must be considered when designing a resource managment system to maximize beneficial effects.

ENVIRONMENTAL CHEMODYNAMICS OF PESTICIDES: PRINCIPLES AFFECTING TRANSLOCATION FROM CROP LAND AND ECOLOGICAL EFFECTS IN THE AQUATIC ENVIRONMENT

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Most pesticides used in Illinois are applied directly to the soil in the spring for the control of weeds and insects. Virtually all agricultural land is treated with a herbicide, and approximately 5 to 7 million acres of corn may be treated each year with an insecticide. The vast majority of insecticides are applied at planting time to control corn rootworms (Table 1). About 70 percent of the soil insecticides are used in the northern-third of the state where corn-on-corn cropping sequences predominate. The topography in this part of the state tends to be rolling, and therefore susceptible to soil erosion. Since pesticide application occurs during periods of heavy rains and consequently, high soil erosion, pesticide translocation to aquatic systems is a highly probable event. Although it has been shown that very small percentages of the applied pesticides actually move during runoff, some insecticides commonly used in Illinois are highly toxic to aquatic invertebrates and fish at very low concentrations.

Over the last 15 years a dramatic change in the kinds of insecticides used in Illinois has taken place. The use of broadcasted applications of extremely persistent chemicals has given way to the use of banded applications of more "biodegradable" compounds. Three classes of insecticides are currently registered for use in Illinois, organophosphates (e.g., chlorpyrifos, isofenphos, phorate, terbufos), carbamates (e.g., carbofuran, carbaryl), and pyrethroids (fenvalerate, permethrin). All are neurotoxicants with low (pyrethroids) to high (organophosphates, carbamates) acute toxicities to mammals. The organophosphates and carbamates are direct inhibitors of acetylcholinesterase enzyme in the central nervous system, whereas the pyrethroids interact with the nerve membrane.

The herbicides are directly sprayed to the soil before, at, or after planting. In some cases weeds may be sprayed directly after crop emergence. The herbicides constitute a wide diversity of chemical classes with the more heavily used ones belonging to the triazines (atrazine, cyanazine), dinitroanilines (trifluralin), acylanilides (alachlor, metolachlor), and phenoxyacetates (2,4-D). The modes of action of the herbicides are poorly understood and less specific compared to the mechanisms know for the insecticides. In general, herbicides are one or more orders of magnitude less toxic to fish and mammals than the insecticides.

A thorough understanding of the fate, behavior, and toxicity of pesticides is required to help conserve water quality. The hazard of any chemical to an organism is a function of exposure and dose, i.e., how much chemical contacts the organism and how much chemical is actually absorbed by the body. Pesticide exposure is dependent on the environmental behavior of the chemical

in addition to the biological habitat of the organism. The area of study concerned with the relationship between environment behavior and exposure is called environmental chemodynamics and it includes four basic areas of research (Haque and Freed 1974):

1. physicochemical properties of pesticides that influence their behavior in the environment;

2. mechanisms of partitioning of pesticides among all environmental components (i.e., air, water, soil, biota);

3. attenuation processes affecting pesticide fate (e.g., photodecomposition, chemical and microbial degradation, etc.);

4. understanding and modeling of environmental transport processes.

The ultimate objective of environmental chemodynamic research is to better assess the exposure of a pesticide (or any contaminant) to either target or non-target organisms. Exposure is dependent on environmental distribution of the pesticide, and therefore the ecological impact of the pesticide is directly related to the ongoing chemodynamic processes.

The following presentation uses environmental chemodynamic principles to better understand the contributions and limitations of conversation tillage practices in preventing pesticide runoff into aquatic systems. Specifically, four topics are discussed: the physicochemical properties of the pesticide; pesticide attenuation processes; impact of conservation tillage on pesticide translocation; and bioconcentration and toxicity.

The Importance of Physicochemical Properties

The fate and behavior of a pesticide are determined by the distribution of the chemical among the various ecosystem components. The components (or compartments) of an ecosystem can be visualized as distinct phases with the pesticide concentration in any phase being a function of both the chemical and the phase characteristics (Haque and Freed 1974). The distribution of a chemical can be visualized as a partitioning or movement of that chemical across the interfaces formed by the various environmental phases, e.g., water/air, water/sediment, water/biotic, sediment/biotic, and biotic/biotic interface. Although many specific properties can affect this environmental partitioning, water solubility, partition coefficient, soil adsorption coefficient, and vapor pressure are the most significant. These properties are not absolute, i.e., a range of values for each property exists depending on the ambient environmental conditions under which they are measured.

Water solubility is probably the single most important property affecting pesticide distribution. It is a measure of the tendency of like molecules to disperse from one another when placed in an aqueous phase. The actual solubility of a pesticide under environmental conditions may be quite

different than its measured solubility in distilled water due to the presence of other dissolved substances (Tulp and Hutzinger 1978). For example, the presence of salts generally reduced the solubility of nonpolar compounds (Masterton and Lee 1972; Felsot and Dahm 1979), while dissolved humic acids can increase the apparent solubility (Ogner and Schnitzer 1970; Matsuda and Schnitzer 1971).

The partition coefficient is the tendency for like molecules to move from an aqueous phase into an organic phase. Basically it is a measure of the pesticide affinity for lipophilic (or fatty-type) materials. It is expressed as the ratio of the concentration of the pesticide in a nonpolar solvent (usually octanol) and its concentration in water. The correlation of low water solubility with high partition coefficients is well documented (e.g., Chiou et. al. 1977).

The soil adsorption coefficient reflects the tendency of a molecule in the liquid phase to adhere to or associate with the solid phase components, and it is analogous to the partition coefficient. Larger values of the coefficient indicate that greater percentages of the chemical will be in the adsorbed state. Sorption is a dynamic process that is affected by the nature of the soil or sediment components as well as the characteristics of the pesticide. Adsorption is positively correlated with organic carbon content of the adsorbent. By normalizing for organic carbon content, a relatively constant coefficient is obtained. The soil adsorption coefficient is directly correlated with the partition coefficient and inversely correlated with water solubility.

Vapor pressure is a measure of the tendency of like molecules to escape from one another, and it is analogous to the solubility of a compound in air (Tinsley 1979). Vapor pressure can be used to calculate the potential distribution or partitioning of a chemical across the air/water or air/soil interface. In other words, vapor pressure is a major factor in determining the volatilization of chemicals from soil and water surfaces. The value for the air/water partition coefficient is inversely proportional to water solubility and directly proportional to vapor pressure.

The major physicochemical properties of selected pesticides that have been used in Illinois agroecosystems are shown in Table 2. Close inspection of the properties of these pesticides shows significant inverse correlations between the logarithmic transformations of water solubility (K_{ws}), partition coefficient (K_{ow}), and soil adsorption coefficient (K_{oc}) ($r = -0.92$ for K_{ws} vs. K_{ow}; $r = -0.92$ for K_{ws} vs. K_{oc}). There is a significant positive correlation between K_{ow} and K_{oc} ($r = 0.91$). These natural physical associations among the physicochemical properties has led to the development of quantitative relationships that are used to predict the distribution of pesticides across environmental interfaces (e.g., Briggs 1981).

Pesticide Attenuation Processes in Soil

After a pesticide is applied to the soil, various phenomena will reduce or attenuate its concentration and ultimately influence the amount that may leave the application site and enter the aquatic environment. Upon contacting the soil, some of the pesticide will adhere to the particulate surfaces (adsorption) and some will dissolve into the water phase. The proportion of the pesticide in each phase is strongly influenced by its water solubility and soil adsorption coefficient and by the soil characteristics. A small fraction of the pesticide may volatilize into the air. The concentration of the insecticide will gradually decrease regardless of the soil phase it is associated with. The processes causing pesticide dissipation can be divided into biological and nonbiological mechanisms. Both mechanisms are strongly influenced by soil sorption phenomena.

Most pesticides are partially or completely degraded by soil microorganisms. Microbial metabolism of a pesticide eventually leads to a loss of its bioactivity (inactivation), but for some pesticides the primary reaction can be an activation to equitoxic products. Usually these products are more water soluble than the parent pesticide and are quickly degraded. The rate of microbial metabolism is greatly influenced by soil conditions and the inherent structure of the pesticide. Some molecules, such as the chlorinated cyclodienes, are incompletely degraded and are denoted as recalcitrant. These kinds of chemicals are likely to be available for translocation from the application site for long periods of time. Other chemicals, such as the organophosphate and carbamate insecticides and many of the herbicides, are easily and quickly degraded by soil microorganisms and therefore only transiently contributed to nontarget pesticide contamination.

Abiotic (nonbiological) mechanisms of pesticide attenuation include chemical degradation and translocation phenomena. Pesticide adsorption takes place on both soil organic matter and clays. Adsorption by organic matter may protect the pesticide from further dissipation processes. On the other hand, adsorption by clay may promote catalytic hydrolysis (i.e., breakdown) of some pesticide classes (Yaron 1978). In general, pesticides persist longer in soils of higher organic matter content but this longevity is dependent on soil pH, moisture and temperature. For example, extremes in soil pH (e.g., below 4.0 and above 8.0) may promote the chemical hydrolysis of certain pesticides.

Translocation processes include volatilization of the pesticide from the soil surface, leaching from the zone of treatment, and surface runoff. These processes reduce the effective concentration of pesticide and are influenced by the formulation, adsorption, cover crop, and tillage practices. Adsorption of the pesticide by soil retards volatilization but increasing soil moisture and temperature can enhance loss. Leaching is also retarded by adsorption phenomena, but cold, sandy soil and high rainfall can accelerate leaching.

Pesticide runoff losses are affected by four variables (Wauchope and Leonard 1980): rainfall timing, hydrologic and soil characteristics of the field; pesticide chemistry, formulation, persistence, concentration; and pesticide target (i.e., soil or foliage). Greater amounts of pesticide runoff will occur as the interval between application and rainfall is shortened (White et al. 1967; Wauchope 1978). During the interim between application and rainfall, attenuation processes will be important in decreasing the amount of pesticide available to surface runoff. The bulk of pesticide runoff occurs early in a rainfall event and less occurs in subsequent rainfalls (Table 3, Baker et al. 1978). Since fields with steep slopes and watersheds experience higher amounts of water runoff and erosion, more pesticide runoff is expected. Wauchope (1978) has presented a general classification scheme for estimating the amounts of pesticide runoff expected on the basis of formulation, chemistry, slope, and storm timing (Table 4). Under worst case conditions, less than 5 percent of the total amount of pesticide applied is expected to be lost by surface runoff.

Pesticide in surface runoff are either dissolved in the moving liquid phase or are adsorbed to various soil particulates. The distribution of the pesticide between the solid and liquid components depends on the soil adsorption coefficient. Highly adsorbed chemical (such as the chlorinated hydrocarbon and cyclodiene insecticides) would be expected to move mainly in the sediment runoff, whereas the more water soluble carbamate insecticides and herbicides would be transported in the water phase. This point has been demonstrated by both field and laboratory experiments. Caro (1975) observed that equal proportions of dieldrin and carbofuran insecticides were lost in runoff from an experimental watershed even though the physicochemical properties of these insecticides are very different. Felsot and Wilson (1980) showed that 100 times more dieldrin than carbofuran was adsorbed to a variety of soils; coincidentally, carbofuran was shown to move in the liquid phase on thin layers of soil whereas dieldrin was immobile. These observations indicated that dieldrin was carried via particulate transport, whereas carbofuran moved as a solute in the liquid phase. In a rainfall simulation study, Baker et al. (1978) found that the ratio between fonofos concentration in the sediment and its concentration in water was over 10 times higher than comparable ratios for concentrations of the herbicides, alachlor and cyanazine
(Table 3). Fonofos, an organophosphate soil insecticide, has a water solubility of about 13 ppm and cyanazine and alachlor have solubilities of 171 and 242 ppm, respectively. In general pesticide concentrations are higher in the sediment than in the runoff water, but greater total losses of pesticide are associated with the greater volume of runoff water (Ritter et al. 1974).

Impact of Conservation Tillage on Pesticide Translocation

In considering the impact of conservation tillage practices on pesticide runoff, three questions are raised: 1) Will more pesticides be used?

2) How will degradation be affected? 3) How will translocation be affected? It is generally assumed that weed and insect problems will increase in fields under conservation tillage, but few studies have been published that document this. Coincidentally it is also assumed that higher rates of pesticides will be required to efficiently control pests in agroecosystems under conservation tillage. Recommended rates for insecticides have not changed in response to tillage practices, and herbicide rates have always been adjusted for soil type differences and weed species. Crops under no-till conditions may need slightly higher application rates of preemergent herbicides, but it is more likely that these fields will require more applications of post-emergent herbicides. Conservation tillage practices may not require more soil pesticide use but rather a better understanding of the pest-pesticide interactions in general.

Very little research has been conducted on the effect of conservation tillage on pesticide dissipation rates. It is well known that certain properties of soil under no-till conditions for long periods of time will be different from plowed soils. The properties likely to be affected (e.g., moisture, temperature, organic matter, pH, microbial population) are the same as those that will influence pesticide behavior. Interception of pesticide sprays or granules by crop residue on the soil surface may temporarily delay degradation of the chemical by preventing contact with the soil surface. Eventually the chemical will be washed to the soil surface or carried away by other translocation phenomena (Martin et al. 1978).

There is little doubt that conservation tillage can significantly reduce soil erosion; however water runoff is less affected (Table 5) (Laflen et al. 1978; Siemens and Oschwald 1978; Baker and Johnson 1979). Prevention of soil erosion by an increase in crop residue cover has been show to also decrease insecticide runoff. For example, Baker et al. (1978) observed a 75 percent reduction in fonofos runoff between a conventional-till and a no-till field plot subjected to simulated rainfall (Table 6). Runoff of the more water soluble herbicides that may have been intercepted by the crop residue during application was less affected because more of these chemicals were transported in the water phase (Tables 3 and 6). Under natural rainfall, comparatively less water, soil, and pesticide runoff occurred in a small watershed under conservation tillage than under conventional tillage, but pesticide concentrations in sediment and/or water were sometimes higher for conservation tillage systems (Baker and Johnson 1979). In sum, conservation tillage practices app4ear to be effective in greatly reducing insecticide runoff but have comparatively less impact on herbicide runoff.

Ecological Impact: Bioconcentration and Toxicity

The corollary of environmental chemodynamics as the processes affecting exposure is toxicodynamics as the processes influencing the actual expression of toxicity. This field of study comprises by definition the dynamic aspects of intoxication, i.e., the interaction of the chemical with specific target tissues, and the kinetic aspects of intoxication, i.e., the processes

controlling the time course of chemical concentration in various tissues and biological availability (Welling 1979). In other words, toxicodynamics is the sum of the processes which affect the behavior of the chemical within the organism and includes penetration, binding and storage, biochemical conversions, and reactions with the target organ.

Bioconcentration of a pesticide may be viewed as the link between environmental chemodynamics and toxicodynamics. It has been defined "as the amount of a pesticide residue accumulated by an organism by adsorption, and by absorption via oral or other route of entry which results in an increased concentration of the pesticide by the organism or specific tissues" (Kenaga 1973). The environmental distribution and fate of a pesticide will determine its potential exposure or dose to the various biotic components. The actual amount accumulated is a function of the physicochemical properties of the pesticide and toxicodynamics within the organism.

The bioconcentration factor is the ratio of the measured pesticide residue in the organism compared to the residue in the ambient environment. Various pesticides can be assigned relatively specific bioconcentration factors (i.e., values within the same order of magnitude) that indicate the tendency to accumulate in an organism. Furthermore, significant direct correlations have been observed between bioconcentration factors and physicochemical properties such as water solubility and partition coefficient (Chiou et al. 1977; Kenaga 1980). For any one pesticide/organism combination, however, bioconcentration is most influenced by chemical persistence, physicochemical properties, surface area, metabolism, and ecological factors such as habitat and trophic level (Tinsely 1979; Kenaga 1973).

Although aquatic organisms can accumulate pesticides via food ingestion, current research stresses the importance of direct uptake from the environment. For fish, the fill surfaces would be most effective at concentrating pesticides, whereas the entire exoskeleton of insects would be an effective surface. Even passive life stages of an organism, such as insect eggs, can bioconcentrate large quantities of pesticides (Belluck and Felsot 1981).

In general the chlorinated cyclodiene, organophosphate, and pyrethroid insecticides are extremely toxic to fish at concentrations in the low parts per billion range (Table 7). The carbamate insecticides and herbicides are significantly less toxic to fish but not necessarily to arthropods such ad Daphnia. Although a sublethal concentration of pesticide may not cause mortality, enzyme systems can still be affected. For example, the brain acetylcholinesterase level of bluegill sunfish exposed to a sublethal concentration of 1.7 ppb chlorpyrifos insecticide was significantly inhibited compared to unexposed fish (Felsot and Reinbold, unpublished). Furthermore, the effect on aquatic organisms from exposure to mixtures of chemicals that would normally be present in surface runoff is largely unknown.

In conclusion, conservation tillage practices can reduce sediment transport of adsorbed pesticides to aquatic systems. This reduction in pesticide runoff will have a beneficial impact in watershed areas since it is the more acutely toxic insecticides that are preferentially translocated in the soil phase of runoff. Conservation tillage practices that also reduce water runoff will prevent herbicide runoff, but at present it appears that runoff of these more soluble chemicals that are intercepted by the crop residue will not be prevented. More research is needed to better characterize the fate and behavior of pesticides in conservation tillage systems and the impact on aquatic organisms that would be exposed to complex mixtures of agrichemicals.

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Table 1. Illinois acreage treated with insecticides (Colwell 1983).

Crop/insect	Acres treated 1982	Acres treated 1981
CORN		
rootworms, cutworms (prepl.)	5,486,000	5,737,000
cutworms (post-plant)	406,000	596,000
European corn borer	223,000	222,000
others	62,000	182,000
SOYBEANS		
bean leaf beetle	42,000	51,000
others	20,000	16,000
ALFALFA		
alfalfa weevil	127,000	161,000
potato leafhopper	116,000	105,000
others	18,000	16,000
SORGHUM	7,000	7,000
TOTAL	6,507,000	7,093,000

Table 2. Physicochemical properties of selected pesticides that have been used in Illinois agroecosystems.

Pesticide	Water solubility (ppm)	Log partition coefficient	Log soil adsorption coefficient	Vapor (mm Hg) pressure
Insecticides				
chlorpyrifos	1.12[2]	5.11[1]	4.00[2]	1.9×10^{-5}[3]
phorate	20.0[2]	3.33[2]	2.61[2]	2.3×10^{-3}[4]
terbufos	5.1[2]	3.68[2]	2.78[2]	2.6×10^{-4}[5]
carbaryl	83.0[6]	2.32[14]	2.59[6]	5.0×10^{-3}[19]
carbofuran	320.0[7]	1.60[15]	1.68[8]	2.0×10^{-5}[9]
DDT	0.0012[12]	5.98[15]	5.38[10]	1.9×10^{-7}[3]
aldrin	0.027[13]	7.40[14]	4.45[14]	6.0×10^{-6}[4]
Herbicides				
atrazine	33.0[10]	2.68[15]	2.17[10]	3.0×10^{-7}[4]
trifluralin	0.3[6]	5.34[15]	3.97[17]	2.4×10^{-4}[11]
alachlor	242.0[18]	2.92[15]	2.28[10]	2.2×10^{-5}[18]
cyanazine	171.0[18]	2.18[15]	2.30[10]	1.0×10^{-8}[18]
2,4-D	900.0[3]	2.81[16]	1.78[3]	6.0×10^{-7}[3]

1/ Chiou et al. (1977)
2/ Felsot and Dahm (1979)
3/ McCall et al. (1980)
4/ Weber (1972)
5/ Jamet and Piedallu (1978)
6/ Swann et al. (1980, ACS)
7/ Bowman and Sani (1979)
8/ Felsot and Wilson (1980)
9/ FMC Corporation
10/ Kenaga (1980)
11/ Spencer and Cliath (1977)
12/ Bowman et al. (1960)
13/ Park and Bruce (1968)
14/ Briggs (1981)
15/ Kenaga and Goring (1980)
16/ Fujita et al. (1964)
17/ Kanazawa (1981)
18/ Weed Science Soc. of Am. (1979)
19/ Spencer (1973)

Table 3. Average pesticide concentrations in water and sediment during the first-third (A), last two-thirds (B), and an additional two rains (C) on ida soil (12% slope; average of all tillage systems studied) (modified from Baker et al. 1978).

	PPB pesticide in rainfall fraction								
	Fonofos			Alachlor			Cyanazine		
	A	B	C	A	B	C	A	B	C
Sediment	1360	950	670	2333	11$\overset{5}{4}$0	510	3030	1240	420
Water	19	8	6	470	170	70	620	200	80
Ratio	76	119	112	5	7	7	5	6	5

Table 4. Generalizations for seasonal and long-term losses of pesticides in runoff from fields (adopted from Wauchope 1978).

1. Herbicides applied to soil surface (wettable powders)
   - Highest long-term losses of any general class
   - Losses ≤ 5% from fields of moderate slope (10-15%)
   - Losses ≤ 2% from fields of low slope (<3%)
   - Sensitive to storm timing, "2 week critical period"

2. Foliar applied insecticides (emulsions)
   - Losses ≤ 1%
   - Greater losses if highly persistent
   - Highly persistent pesticides less sensitive to storm timing

3. Water-soluble pesticides (aqueous solutions) and soil-incorporated pesticides
   - Losses ≤ 0.5%
   - Incorporated pesticides less sensitive to storm timing

Table 5. Effect of tillage on residue cover, runoff, and soil erosion in an Ida soil (12% slope) after 216 mm of rain in a rainfall simulation study (modified from Laflen et al. 1978).

Tillage practice	% cover	Runoff (mm)	Erosion (T/ha)
Conventional (moldboard plow)	9	118	57.8
Reduced (chisel plow)	23	108	42.7
No-till (fluted coulter)	58	57	8.2

Table 6. Percent of applied pesticide lost with 216 mm of precipitation on Ida soil (12% slope) in a rainfall simulation study (modified from Baker et al. 1978).

Tillage	% cover	Fonofos	Alachlor	Cyanazine
Conventional	9	3.2	5.3	5.3
Reduced	23	2.1	7.2	7.7
No-till	58	0.8	2.7	3.8

Table 7. Acute toxicity of selected pesticides to fish and aquatic invertebrates (adopted from Johnson and Finley, 1980, unless otherwise noted).

Pesticide	96h LC_{50} bluegills (ppb)	48h EC_{50} Daphnia (ppb)
Dieldrin	3.1	190
Heptachlor	5.3-13	42
Chlorpyrifos	2.4	
Fonofos	7.0	
Phorate	2.0	
Terbufos	4.0	
Carbaryl	>6760	6.4
Carbofuran	240	
Permethrin	8.8-61 1/,2/	
Fenvalerate	11 1/,2/	
Alachlor	3200-4300	
Atrazine	12600 1/,3/	3600 3/
Cyanazine	22500	
2,4-D	540-81600	>100000
Trifluralin	58	560-625

1/ Rainbow trout

2/ Coats and O'Donnell-Jeffery (1979)

3/ Brown (1978)

INSTREAM SEDIMENT MOVEMENT IN ILLINOIS

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Introduction

The hydraulics of flow in a natural stream and the stream's sediment transport characteristics are the two basic phenomena that determine its geometric and planform shape. There are many variables that affect the hydraulics of flow and the nature of sediment transport in a river, and any change or alternation in these variables can generate a chain reaction that may be detrimental to the total system of "river flow". Streams and rivers are subjected to a number of man-made constraints, and sometimes the effects on these constraints may not show up for a long time.

The behavior, characteristics, and nature of streams are somewhat different depending upon whether they flow on steep gradients, such as in mountainous areas of the country, or on flat terrains, such as in the Midwest. The materials through which a river flows, the characteristics of the watershed, the rainfall-runoff pattern of the basin, the constraints imposed by humans, and the geology of the watershed are some of the factors that determine the hydraulic and sediment transport characteristics of the river.

Many investigators have worked in this broad field of hydraulics of flow and sediment transport in streams; however, there has been very little research in which a comprehensive data collection program has been combined with a detailed analysis of the data. Most of the work has been fragmental, in that either the hydraulic data or sediment data were collected from one or two locations. This paper presents results from an intensive sediment data collection program carried out for the state of Illinois. It also provides generalized analyses of the data and identifies some areas of the state where sediment load may be a problem.

Stream Sediment in Illinois

Sedimentation in Illinois lakes and sediment transported by Illinois streams are major pollution issues. The interactions between sediment and water are now recognized as major water resources problems, the magnitude of which has not yet been fully realized.

Various physical means to control soil erosion and stream erosion are now being considered. Their implementation will have enormous societal and environmental ramifications. Unfortunately, many of the physical and chemical aspects of sediments in rivers and lakes are not yet known or understood clearly.

The impacts of sediments in Illinois water related to a multitude of agency and business decisions in Illinois. For example, there are major questions with poorly quantified information on:

- Impacts of sediment on stream biota and stream environment
- Impacts of sediment on water treatment plants
- Lake sedimentation
- Locations and causes of sheet, gully, and stream bank erosion
- Effects of reduced field erosion on instream erosion
- Pollutants carried by sediment
- Quantity and magnitudes of sediment carried by Illinois streams

The state needs a strategy to deal with these impacts, and it needs to make regulatory decisions related to:

- Reduction in watershed erosion
- Best management practices to be followed
- Effects of changing land use and cropping patterns
- Stream channelization
- Land use and management along stream banks and lake shores

Sedimentation also affects the capacity and water quality of water supply lakes and reduces storage capacity in flood control reservoirs. Sediment deposition in streams affects the conveyance of the stream and its capacity to sustain a viable aquatic habitat. The biota in all of these waters are potentially affected by the chemical composition of the sediments, sediment deposition, and sediment load.

As a consequence of these complex, wide-ranging impacts, sediment is of concern in major state activities. These include: 1) the maintenance of water quality; 2) agriculture; 3) regulation of our waterways, construction of hydraulic structures, and development of surface water impoundments, and 4) the preservation of natural stream courses. All of these areas relate to the overall maintenance and management of the state's natural resources.

Correct answers to the myriad of technological, scientific, and policy questions can come only from quality data of sufficient breadth, in both time and space. Data are among the key components to the formulation of plans and policy. Unfortunately, the data base is not adequate in quantity or quality.

To address some of the issues related to instream sediment movement, a statewide sediment monitoring network was initiated with the help of various state agencies. The results presented here are based on the analyses of the data collected for this network. For further information, the reader is referred to the publication by Bonini et al. (1983).

Background

Most of the major rivers of the world flow through alluvial materials consisting mainly of sand and silt. The flow of water in these alluvial channels has been studies by various researchers for many years. In a sand bed channel, the flow velocity, the turbulence associated with the flow velocity, and the patterns of the secondary circulation all have the capability and the opportunity to mold the shape of the channel. Researchers have tried to express the characteristics of flow in alluvial channels in terms of theoretical relationships. Some of their attempts have been successful, whereas others have met with failure. The flow in a natural channel, however, is obviously affected by so many variables that a clear and straightforward analysis is not possible unless one resorts to some acceptable simplifications and assumptions.

As a result of all the constraints in an alluvial channel, a velocity distribution with both lateral and vertical components is developed. These velocity components vary in time and space. The longitudinal water surface slope, or the hydraulic gradient, also constantly adjusts to reflect the constraints of the channel geometry on the flow in a natural channel. This variability of the water surface profile is more pronounced for flow around a bend than it is for a straight reach of the river.

Resistance to flow in an alluvial channel is a function of many variables, which in turn determine the bed form in an alluvial channel flowing on a sand bed. Simons and Richardson (1971) have classified the bed form in two categories: "lower flow regime" and "upper flow regime". Most stable alluvial sand bed channels generally flow on a bed where the bed forms are either dunes or dunes with superimposed ripples. Many times bed forms change from one cross section to the next and even within the same cross section. Even though the turbulent flow in a rigid boundary channel is mostly independent of viscous drag, on a sand bed channel this may not be true. With fine sediment in suspension the flow in a sand bed channel during turbulent flow is affected by a change in viscosity with a change in temperature or a change in the concentration of suspended sediment load.

Motion of the bed materials begins when the hydrodynamic forces exerted on the individual particles are large enough to dislodge the particles from the bed. There are three modes of transport: 1) translation, 2) lifting, and 3) rotation. Incipient motion of bed particles has been analyzed either theoretically or on a semi-empirical basis by many researchers including Shield, as cited by Simons and Senturk (1977); Gessler (1971); and others.

Sediment Load

For the purpose of analysis, the total sediment load is often split into two parts: bed load and suspended load. Bed load is defined as that sediment in the bed layer moved by saltation (jumping), rolling, or sliding. The bed layer is a flow layer several grain diameters thick immediately above the

bed. Its thickness is usually taken as 2 grain diameters (Einstein, 1950). Suspended load is defined as that sediment load which is moved by upward components of turbulent currents and which stays in suspension for a considerable time.

There is no sharp division between saltation and suspension. The distinction is made between the two different methods of hydraulic transport: movement due to shear force and movement due to suspension.

Bed Load — There are many bed load equations that can be used to predict sediment transport rates of different grain sizes. These equations predict the transport capability of the stream, which generally equals the available supply of sediment from the upslope terrain. Whenever the supply of sediment is less than the transport capability of the stream, the transport capacity of the river will exceed the available supply. In such an instance, bank erosion or bed scour may occur.

It must be stated here that bed load is hard to define. All bed load equations are empirical or semi-empirical in nature and have some similarities. When these equations are applied, care should be taken to limit their use to similar flow conditions and particle characteristics.

Suspended Load — Suspended load is defined as that sediment surrounded by fluid that stays in suspension for an appreciable length of time. Sediment particles settle because of their weight, but fluid turbulence counterbalances this motion. Just as there exists an active exchange between bed material and bed load, there is an active exchange between bed load and suspended load.

When attempting to determine the suspended load one must remember that only the suspended load due to bed material can be calculated from available equations. Wash load is determined by available upslope supply rate.

The total load can be obtained from the sum of the bed load and suspended load. Some researchers have attempted to determine total load directly from all the particles sizes that make up the bed. The wash load is made up of particles finer than those found in the bed and is dependent on the supply available from the watershed.

Still, the question remains of how to determine the total load if some field data are available. If the hydraulic and suspended sediment load data are available, the total suspended sediment load can be computed. In many instances, especially in the case of streams flowing on sandy beds, it is easy to measure the suspended sediment load. However, present instrumentations are not yet well enough developed to measure the bed load. For cases such as these, an empirical relationship is needed to determine the total load based on the hydraulic data and the measured suspended sediment load. Simons and Senturk (1977) have indicated that for a large and deep river, the amount of bed load may be about 5 to 25 percent of the suspended

load. Total bed load may be small in these rivers, but it is important since bed load influences the bed stability and determines the bed and grain roughness of the channel.

Data Collection

Initially, data from 50 sites located at the existing stream gaging locations were collected. These stations are shown in Figure 1. The network shown in Figure 1 has been modified over the last few years and presently a much reduced network consisting of about 20 stations is in operation.

The Water Survey's sediment data collection program uses methods and instruments compatible with and similar to those used by the U.S. Geological Survey (USGS). This is necessary to insure that the data collected by the Water Survey have the same level of quality control and quality assurance as those collected by the USGS. Descriptions of these methods and instruments are detailed in the U.S. Department of the Interior's series of publications by Buchanan and Somers (1969), Guy (1969), Guy and Norman (1970), and Porterfield (1972).

Field Sampling

Suspended Sediment — Two types of sampling for suspended sediment concentrations were used in this project. First, all weekly and daily samples were collected at a single location, or vertical, in each channel cross section. This location was termed the "box site".

The second type of sediment sampling involved collecting suspended sediment samples at several verticals along the entire channel cross section approximately once every six weeks. The purpose of this sampling was to calibrate the samples taken at the box site by determining the ratio to the sediment concentration at the box site to the average concentration in the entire cross section. This value could then be used to adjust the concentration values at the box site so they would better reflect the average suspended sediment concentration in the channel cross section (Porterfield, 1972).

The equal transit-rate (ETR) method was used to collect the water-sediment samples. In addition, the equal width-increment (EWI) method was used for all the cross section analyses. A complete and detailed discussion of these sampling techniques is given by Guy and Norman (1970).

Laboratory Analysis

Suspended Sediment Concentration — Suspended sediment samples were analyzed by the filtration method or evaporation dish method at the Illinois State Water Survey Sediment and Materials Laboratory. The methods used are described by Guy (1969).

Particle Size — Suspended sediment samples were analyzed for particle size by the pipet/sieve methods described in the National Handbook of Recommended Methods for Data Acquisition (U.S. Geological Survey, 1978). The analyses were conducted in the Water Survey Sediment and Materials Laboratory.

Generalized Analyses

Stream sediment data collected over a period of one to two years are not enough to form the basis for any substantial and detailed generalized analyses. However, it is imperative that an attempt be made to perform a generalized analysis of the sediment load in Illinois even though the data base is minimal.

Before any definite interpretations of these data are made, it must be pointed out that the sediment load values for all the Water Survey monitoring stations shown in the following original illustrations are based on calculations using the instantaneous sediment load, not the daily mean or weekly mean values. These instantaneous sediment loads and their corresponding water discharges were plotted by computer on log-log paper. A least square regression line was then fitted through these plotted values. This was done for all of the Water Survey monitoring stations. Each graph showing the plot of the data and the regression line was examined visually and the correlation coefficients were evaluated to determine whether or not the fit appeared to be good and also to examine the spread of the points around the fitted line. For all stations where the plotted points were found to be reasonable close to the fitted line, the graphs were accepted as being reasonable sediment rating curves for those stations.

It must be pointed out that for many stations, fewer than 40 data points were available from the first year's operation of the network for use in developing the rating curves. Therefore, the regression line that was fitted to these curves probably will change as more and more data become available.

After this review of the rating curves was completed, the regression equations for the selected stations were used to compute the annual sediment load at these stations. Daily mean discharge values were utilized to compute the daily sediment load, and these daily sediment loads were summed for the 365 days in the year to obtain the annual sediment load. Daily discharge values were taken from records published by the U.S. Geological Survey (1981).

The regression equations were developed using instantaneous sediment and water discharge values, while the annual sediment loads were calculated using mean daily discharge values. This approach was selected as the best available option for calculating yearly sediment loads since the sediment record was not collected on a continuous, daily basis by which mean daily sediment discharges could be estimated directly from the field data.

Average Annual Sediment Yield

The calculated annual sediment loads are the total suspended sediment loads in tons per year for each gaging station. The sediment generated within a basin from its sub-watersheds will probably not be uniform. Some areas may contribute two or three times more sediment than other areas. However, if it is assumed that the drainage basin above each gaging station contributed uniformly toward the total sediment load, then the sediment load per unit area of the basin can be computed and a statewide comparison of the sediment yield can be made.

The total calculated annual sediment load from each station operated by the Water Survey was divided by the drainage area above each gaging station, and the average annual suspended sediment yield in tons per square mile was obtained. These values have been plotted and were utilized to draw lines of equal sediment load, as shown in Figure 2.

The isoline plot in Figure 2 shows a clear and unmistakable trend of heavy sediment loads in certain areas of the state. It is obvious from this map that the west-central part of the state, mostly in the Galesburg and Springfield Plains (Leighton et al., 1948) and the bluff areas of the Mississippi River, contributed the maximum sediment loads in Water Year 1981. In the westernmost part of the state, the maximum value was more that 1,500 tons per square mile.

The yearly sediment yield values from the USGS sediment monitoring stations were then plotted with those from the Water Survey stations. This plot is shown in Figure 3. A close examination of this figure and its contour lines, when compared to the contour lines shown in Figure 2, suggests that the relative location of the isolines remains the same. The overall trend in the sediment yield remained unchanged, with the heavier sediment yields occurring in the west-central portion of the state. In fact, the addition of the USGS data to the contour map improves the resolution of the contour lines.

Figure 4 shows an outline of the areas of excessive sediment load for Water Year 1981, based on the contour map shown in Figure 3. In drawing the boundary lines for these areas, the 200 tons per square mile isoline was generally used as a guide. These areas encompass the Wisconsin Driftless Section, Galesburg Plain and Lincoln Hills Section, and portions of the Springfield Plain, Bloomington Ridged Plain, Kankakee Plain, Green River Lowland, and Rock River Hill Country. Portions of the Shawnee Hills Section and Coastal Plain Province are also included (Leighton et al., 1948). In terms of land resource areas of Illinois (IEPA, 1979), these areas cover all of the Northern Mississippi Valley Loess Hills, major portions of the Illinois and Iowa Deep Loess Hills and the Central Mississippi Valley Wooded Slopes, and lesser portions of the Southeastern Wisconsin Drift Plain and the Northern Illinois and Indiana Heavy Till Plain. These areas of excessive sediment load also encompass the intensive row crossing areas of the state.

Another interesting point indicated in Figures 2, 3, and 4 is the increased trend of sediment loads from east to west and from north and south to the central part of the state. If two lines are drawn in Figure 3, one east-west at the 40° north latitude, and another one north-south at the 90° west longitude, and if curves are then plotted for sediment yield versus distance along these lines, the plots appear as shown in Figure 5 and reflect this trend.

In evaluating the sediment yield values presented in Figures 2 through 5, one must remember that these values are for measurements of instream sediment loads. These instream sediment loads include not only the sediment delivered from the upland watersheds, but also the net sediment load generated within the stream environment, such as from bank erosion and bed scour.

Comparison with Other Variables and Data

Two of the most important variables in the generation and transport of sediment in any stream environment are surface runoff and streamflow. Data analyzed from the Kankakee River (Demissie et al., 1983) have clearly demonstrated the variability of sediment load from a relatively dry year to a wet year.

Figure 6 shows the total precipitation by crop district in Illinois for Water Year 1981, in inches. The departures from normal are given under each value within each crop district. If all the areas of above normal precipitation are considered, two boundary areas of excess precipitation can be drawn (Figure 6--solid lines). If the Chicago Metropolitan Area, which is highly urbanized and where agricultural-related sediment generation would be relatively small, is ignored (Figure 6--dashed line), the areas of high precipitation in Water Year 1981 would be very similar to the areas outlined in Figure 4. Figures 4 and 6 seem to indicate that there is a very good correlation between high precipitation and relatively large amounts of sediment load in streams and rivers within the state of Illinois. Therefore, it is obvious that any sediment yield computations or analyses cannot ignore the precipitation variability within a certain area.

Located within the area of high precipitation in Water Year 1981 are the Galesburg and Springfield Plains, two areas with soils that are highly erodible and easily transportable. Therefore, at least three factors which contribute to sediment yields have been matched for Water Year 1981--intense row crop agriculture, relative high precipitation rate, and highly erodible soils.

It may be interesting to compare the sediment isolines shown in Figure 3 with a map developed by the Illinois Environmental Protection Agency (1979) on the average thickness of topsoils in Illinois (Figure 7). A close comparison of Figure 7 and Figure 3 suggests that there is a modest correlation between the sediment yield in Water Year 1981 and the relationship of the present topsoil thickness to the original topsoil thickness. This may indicate that the

trends shown in Figures 2 and 3 have been in existence for a considerable amount of time. The implications of this assessment are, of course, many and varied. Additional field data and research are needed in order to determine whether or not such an assessment is reasonable and valid.

From the analyses presented, it appears that the areas shown in Figure 4 are the areas where resources should be targeted to reduce soil erosion. In the process of evaluating watershed protection strategies and priorities, planners and administrators must direct their limited resources to the areas where the greatest potential benefit may be realized.

Special Analyses of the Kankakee River Data

Some analyses of suspended sediment data which have been collected from the Kankakee River during the last few years are presented here. The Kankakee River, located near the northeastern part of the state, drains about 5200 square miles and flows mostly on a sandy bed. The river has two major parts: the main stem and the Iroquois River.

The runoff and sediment transport characteristics within these two main branches of the Kankakee River are significantly different. In terms of flood peaks and sediment load, the Iroquois River makes a greater contribution on a per unit drainage area basis than the Kankakee River upstream of their confluence. The Iroquois River's peak water and sediment discharges are several times greater than those of the Kankakee River. On the other hand, the Kankakee River contributes much greater discharge than the Iroquois River during periods of low flows. For a detailed discussion of the research conducted for this project, the reader is referred to the publications by Bhowmik et al. (1980), Bhowmik and Bogner (1981), and Demissie et al. (1983).

An examination of the daily variation in water and suspended sediment load will indicate how these two quantities vary over a period of time. Figures 8a-c show the daily water discharge and suspended sediment discharge versus time for the Wilmington gaging station for three consecutive water years starting with Water Year 1979. These plots clearly indicate that the sediment movement is episodic, that it changes from season to season, and that fairly good correlations sometimes exist between the water discharge and the suspended sediment discharges.

Annual Sediment Load — The total annual water discharge and sediment yield at the four stations on the Kankakee River for the three water years are given in Table 1. The average yearly sediment yield based on the three years of data is also given in the table. Annual sediment yields are computed from the daily suspended sediment data.

For the three years of data, there exist very good relationships between the annual sediment yield and water discharge, as shown in Figure 9. The two lines shown in the figure are for the main stem of the Kankakee River and the

Iroquois River. This figure indicates that the relationship between the sediment load and water discharge for the Kankakee River is different from that for the Iroquois River. For the same water discharge, the Iroquois River carries much more suspended sediment than the Kankakee River. This difference results from the geology of the drainage basins. The drainage basin of the Kankakee River upstream of the Momence station is covered for the most part with sand and gravel, while the Iroquois River Basin is covered with mostly fine soils with a lot of silt and clay. This plot also indicates that when long-term data on sediment load are available, it is quite feasible to estimate the historical sediment yield of a river basin.

Cumulative Movement of Sediment Load — As shown in the daily sediment discharge plots, Figure 8a-c, it was obvious that the bulk of the suspended sediment moved during storm events. Since the number of storm events in a year is small and the durations of the storm events are generally short, the bulk of the suspended sediment moves past a station during a relatively small number of days during the year. This is illustrated in Figures 10 a-b for the Chebanse and Wilmington stations, respectively. In each figure, the percentage of the annual suspended sediment moving past the gaging station in a given number of days in shown. The three curves in the figures represent the three water years, as indicated.

From Figures 10a and b, and the computations performed, it became apparent that at the Iroquois, Chebanse, and Wilmington stations, 50 percent of the total sediment load in 1980 moved past the stations in only 6, 4, and 5 days, respectively. For 80 percent of the total sediment load, the corresponding number of days in 1980 at the three stations were 51, 21, and 36 days. It is obvious, therefore, that most of the suspended sediment is transported during the storm events which take place in a relatively short period of time during the year.

Another important observation from Figure 10a-b is the variation of the cumulative sediment transport curve from year to year. The curve for Water Year 1980 has a steeper slope in the initial zone of the cumulative curve than the 1979 water year curve, which in turn has a steeper slope than the 1981 water year curve. The 1980 water year was the driest year among the three years considered, and during this year the highest percentage of the suspended sediment was transported in the shortest period of time at the Chebanse and Wilmington stations. The 1981 water year was slightly wetter than the 1979 water year, and during this year, it took more time for the same percentage of suspended sediment to pass the stations at Chebanse and Wilmington than in 1980 or 1979. Thus, there seems to be a trend of a higher percentage of suspended sediment moving in a shorter number of days during drier years than in wetter years.

Summary and Conclusion

This paper summarizes the data collected from the Illinois State Water Survey Instream Sediment Monitoring Program for Water Year 1981 (October 1980

through September 1981) and some analyses of the data collected from the Kankakee River Basin.

Although the data base is minimal as far as sediment data are concerned, generalized analyses have been included in order to show the variability in the suspended sediment yield in Illinois for Water Year 1981.

According to these analyses, it has been demonstrated that the northwest, west, central, and far southeast parts of the state produced excessive amounts of sediment load in Water Year 1981. Good correlations exist between this excessive sediment load and above normal precipitation rates within these specified areas. The rates of topsoil loss in Illinois and the areas of high sediment yield also indicate a fairly good correlation. There was a gradient of increased sediment yield from the Indiana-Illinois state line close to Danville toward the western part of the state up to the Mississippi River. In Water Year 1981 this gradient from the eastern to the western part of the state (along a line at the 40° north latitude) was such that the sediment yields in the west were nearly seven times higher than those in the east.

The statewide data analyzed for this report were from only a 12-month period. Therefore, any extrapolation and inference that are made from these data should be made with a clear reference to this important constraint.

Analyses of the data from the Kankakee River Basin have shown that the sediment transport is episodic and changes from season to season, and that sometimes good correlations do exist between the sediment load and the water discharge. It has also been shown that on a per unit drainage area basis, the Iroquois River transported much more suspended sediment load than the Kankakee River. For both the river basins, most of the sediment moved during storm periods lasting a few days. Moreover, the runoff magnitude also played an important role in the transportation of the sediment load. In a relatively dry year, almost 80 percent of the yearly sediment load can move within a period lasting about 20 days during heavy storms.

The usefulness of the analyses presented in this paper depends on their application in the decision-making processes when resources are allocated to conserve the natural resources of the state. It is quite apparent that the major effort should be expended in those areas of the state where sediment yield is very high and the reduction in sediment load from conservation practices would be maximum.

Acknowledgements

The research discussed in this paper was conducted by the author with the active participation of many Water Survey employees as part of their regular duties at the Survey. Special thanks are extended to Al Bonini, who was instrumental in the proper operation of the sediment network, and to Mike Demissie and Bill Bogner, who contributed significantly in the Kankakee

project. Many other Water Survey employees also participated quite actively in these projects.

Thanks to the Illinois Environmental Protection Agency and the Illinois Department of Transportation, Division of Water Resources, for their financial support during the initial phases of this project. Support and encouragement were also extended by the Illinois Department of Agriculture, Illinois Department of Conservation, U.S. Geological Survey, and others. A special thanks to our Department of Energy and Natural Resources, which has financially aided the maintenance of this network from the beginning up through the present.

The author extends a very special "Thank you" to Rodger Adams of the Water Survey for formally presenting this paper at this Conference.

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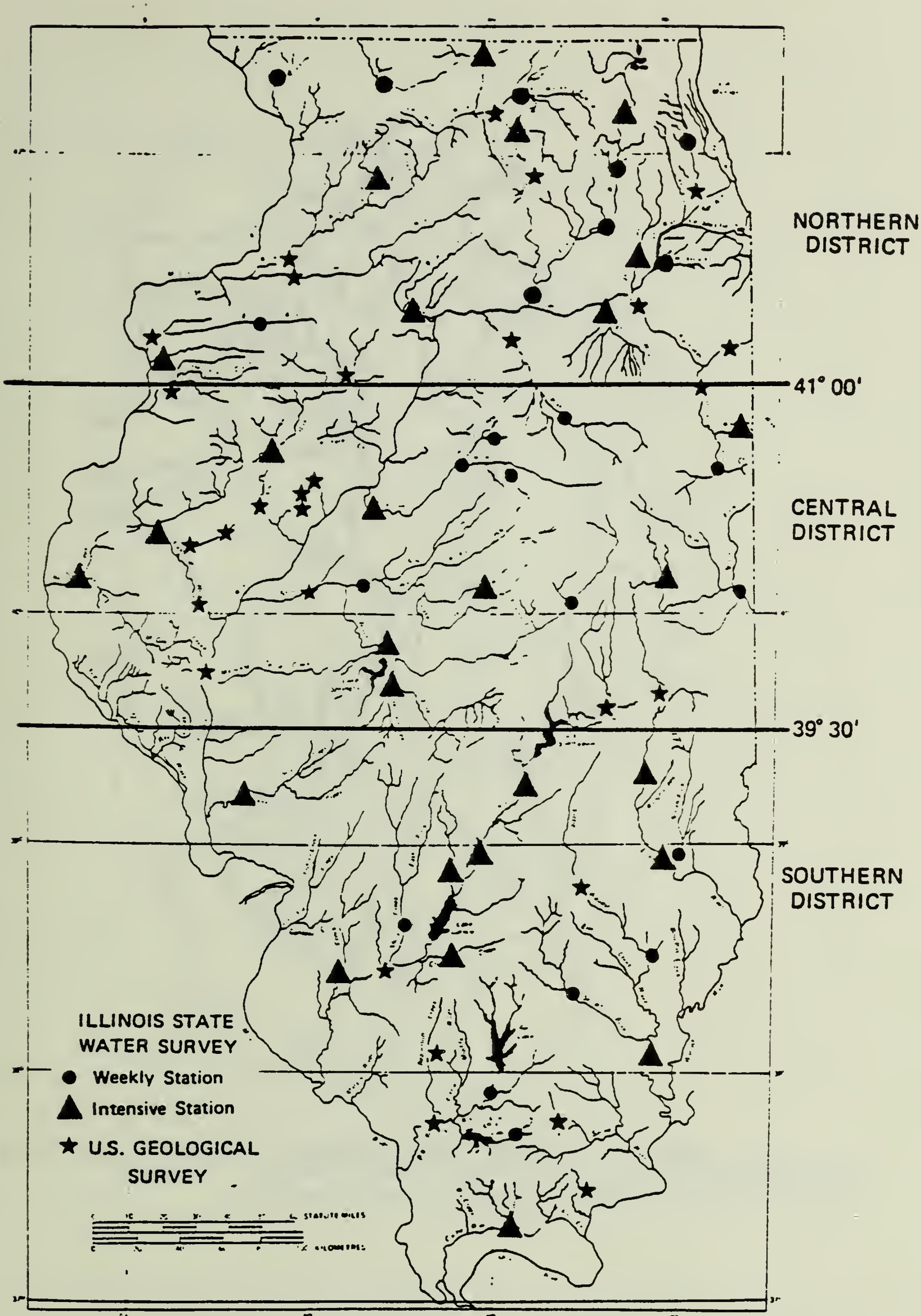


Figure 1. Sediment Monitoring Network for Illinois for Water Year 1981 (October 1980 through September 1981)

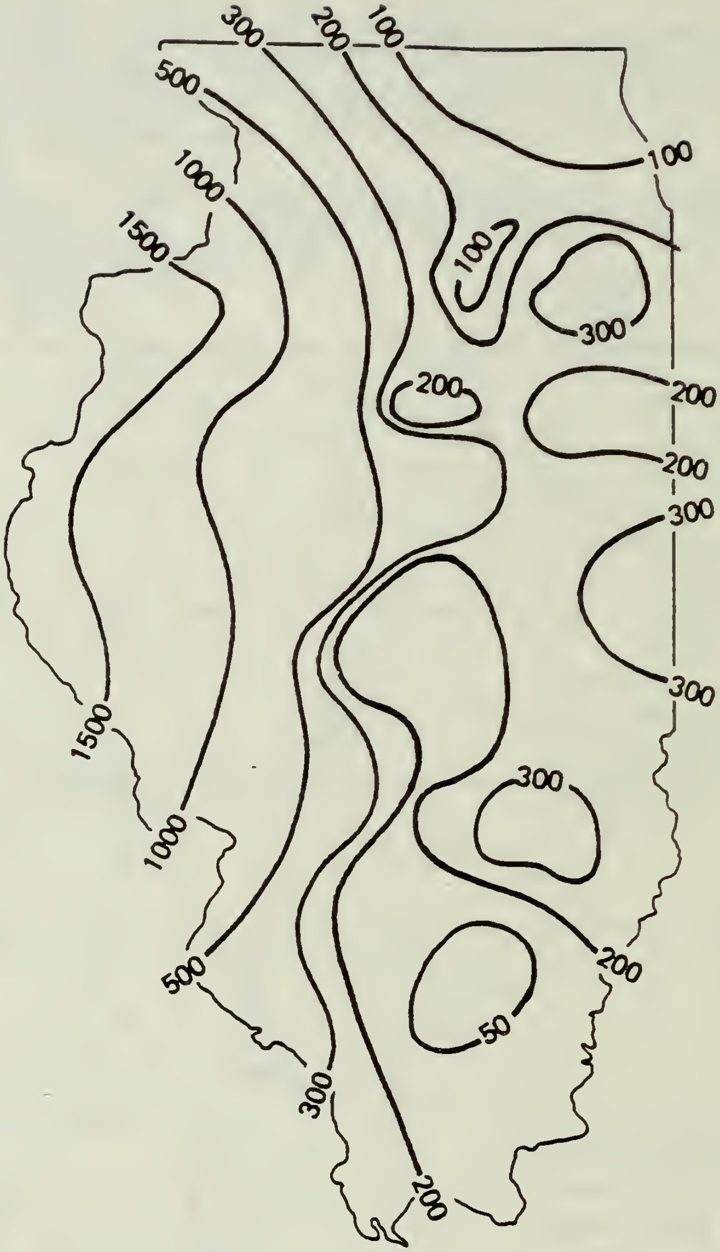


Figure 2. Average annual sediment yield (tons per square mile)

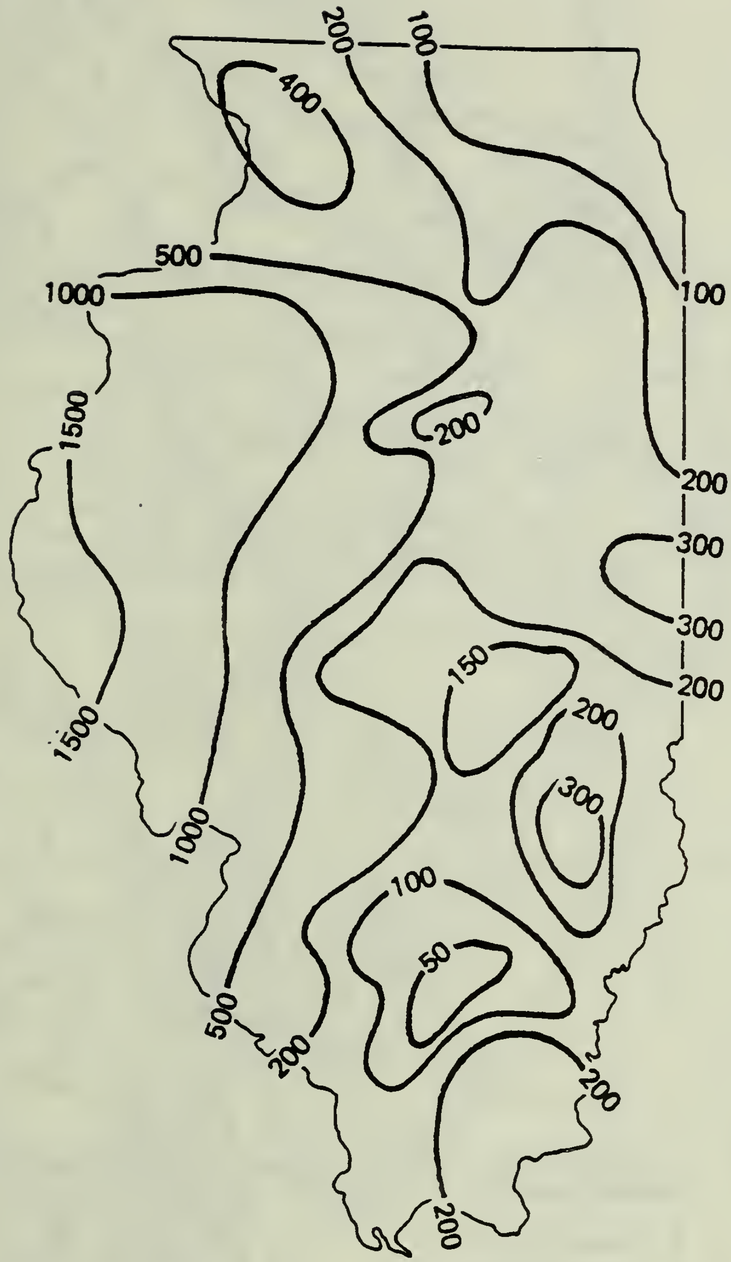


Figure 3. Average annual sediment yield (tons per square mile) including U.S. Geological Survey data (USGS, 1981)

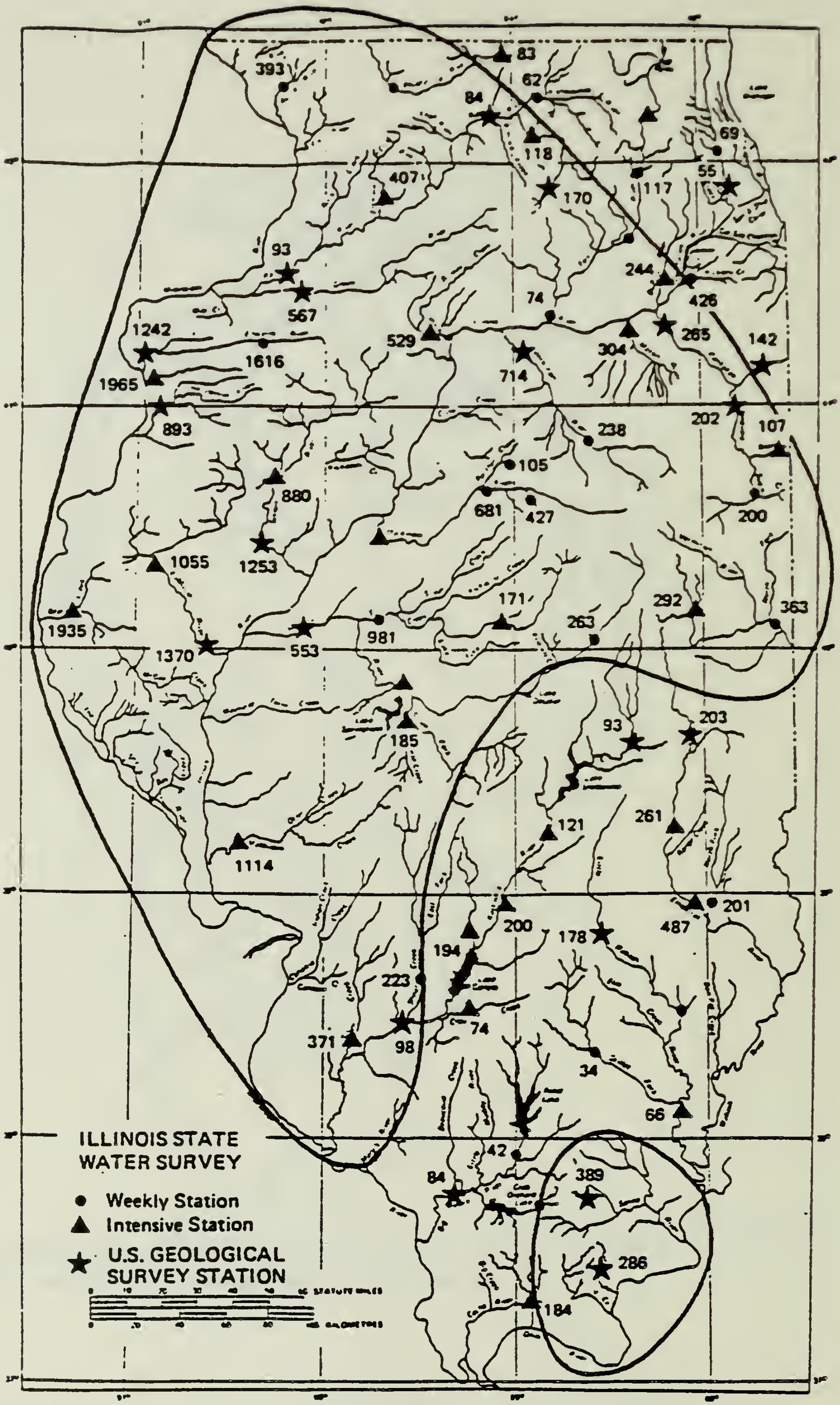


Figure 4. Average annual sediment yield (tons per square mile) and areas of heavy sediment yield

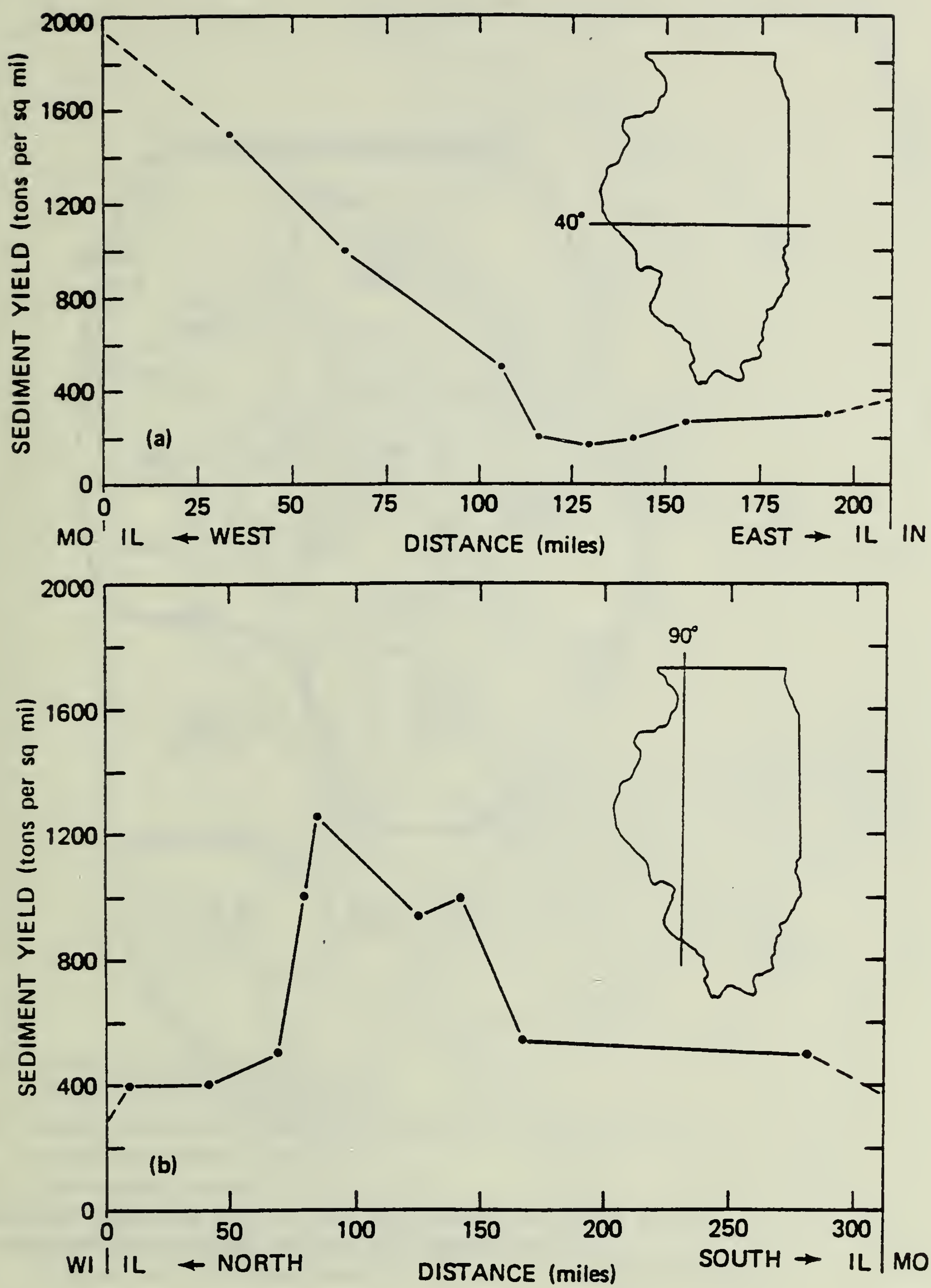


Figure 5. Gradient of the sediment yield in Illinois; sediment yield (tons per square mile) versus distance (miles) along lines at the 40° north latitude and the 90° west longitude

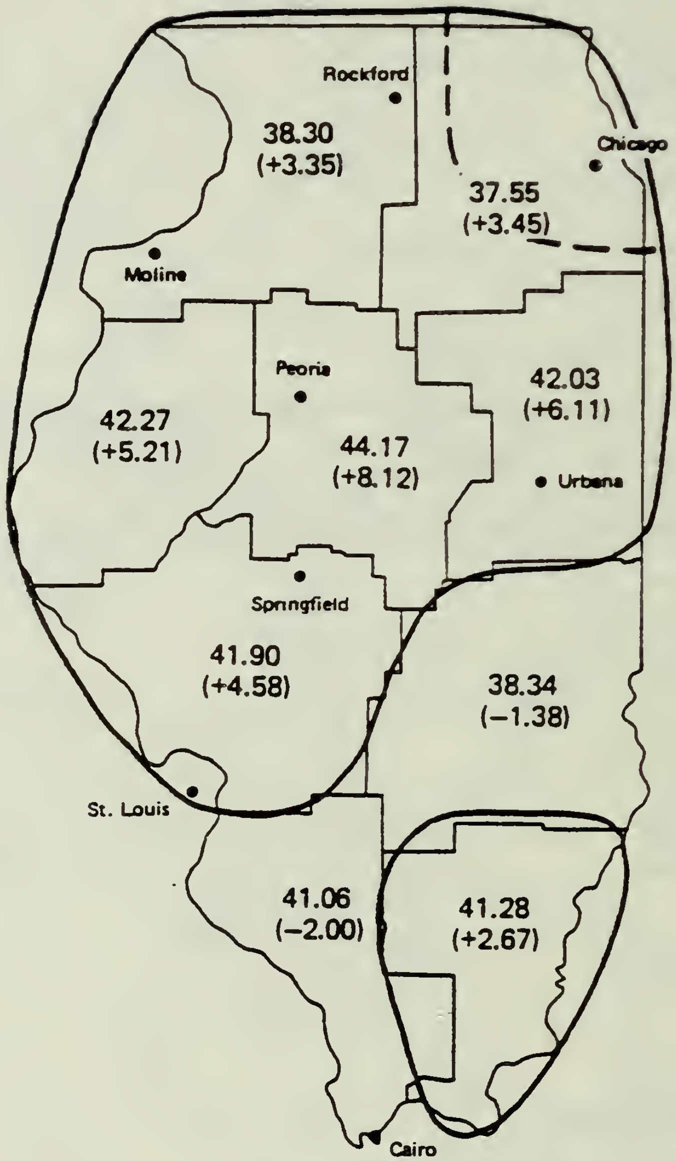
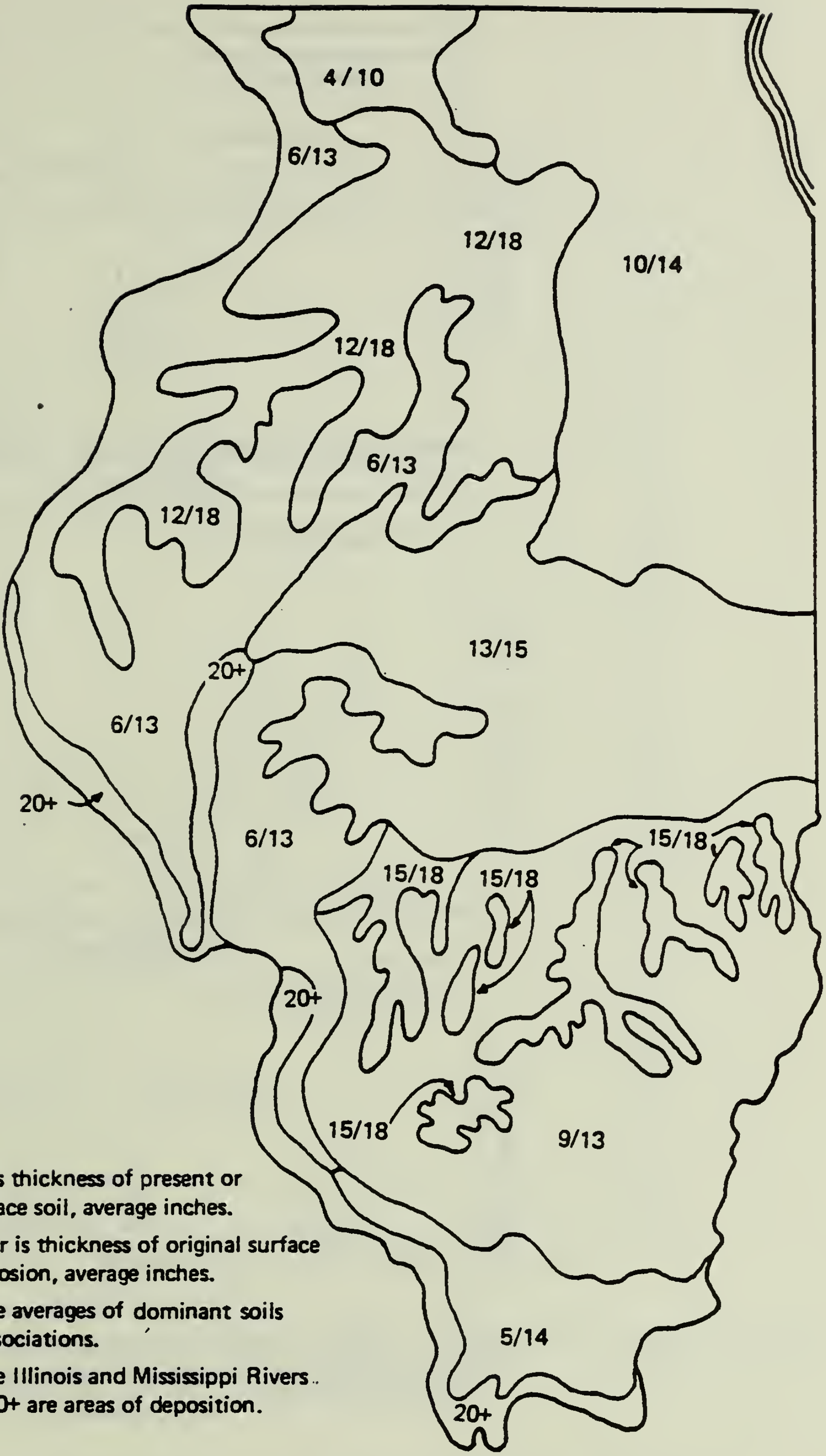


Figure 6. Total precipitation by crop district and departure from normal (in inches) for Water Year 1981



1) First number is thickness of present or remaining surface soil, average inches.
2) Second number is thickness of original surface soil without erosion, average inches.
3) Thicknesses are averages of dominant soils within Soil Associations.
4) Areas along the Illinois and Mississippi Rivers indicated by 20+ are areas of deposition.

Figure 7. Average thickness of topsoils in Illinois (after IEPA, 1979)

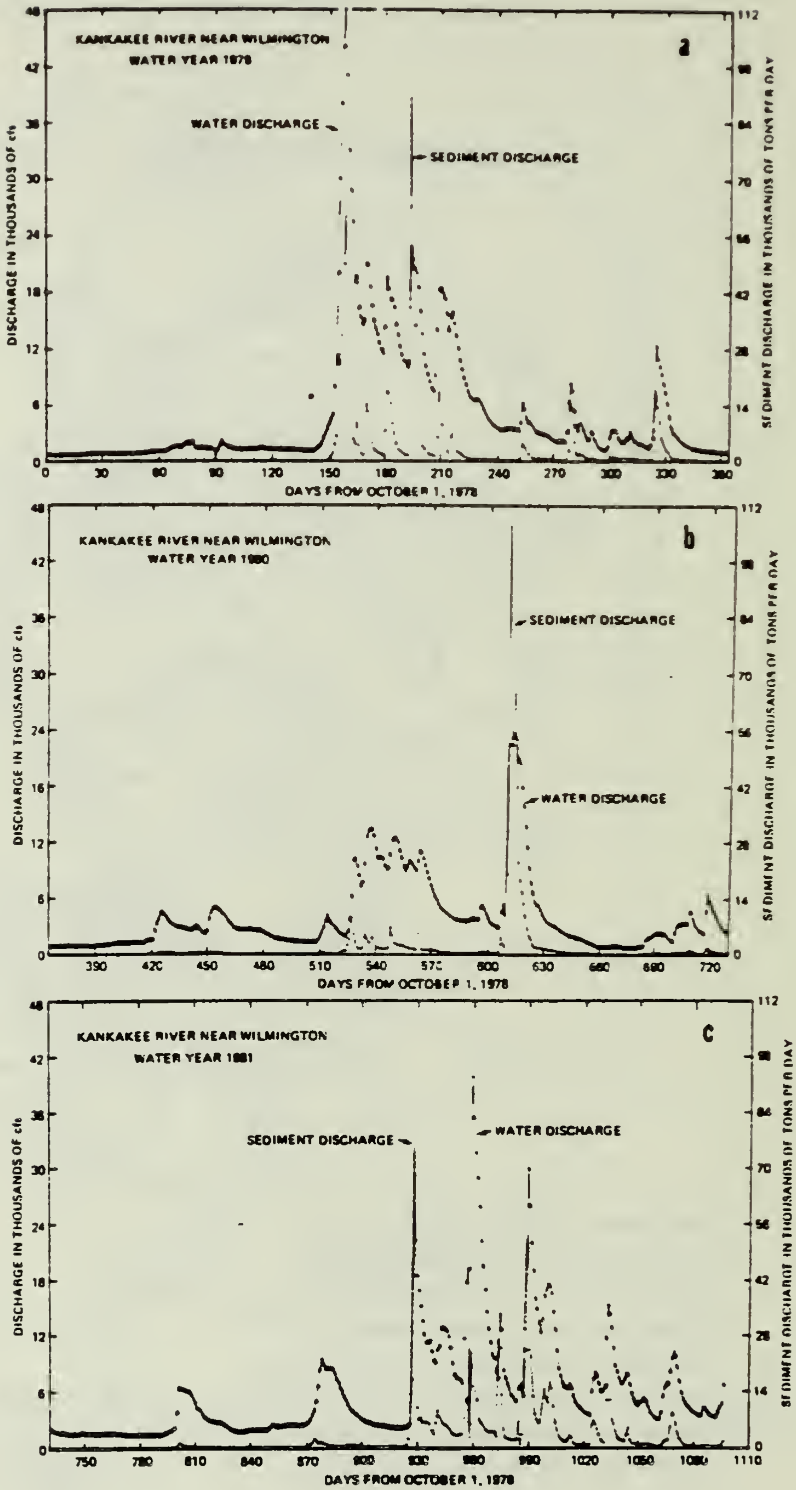


Figure 8. Daily water and suspended sediment discharges for the Kankakee River near Wilmington, Water Years 1979, 1980 and 1981

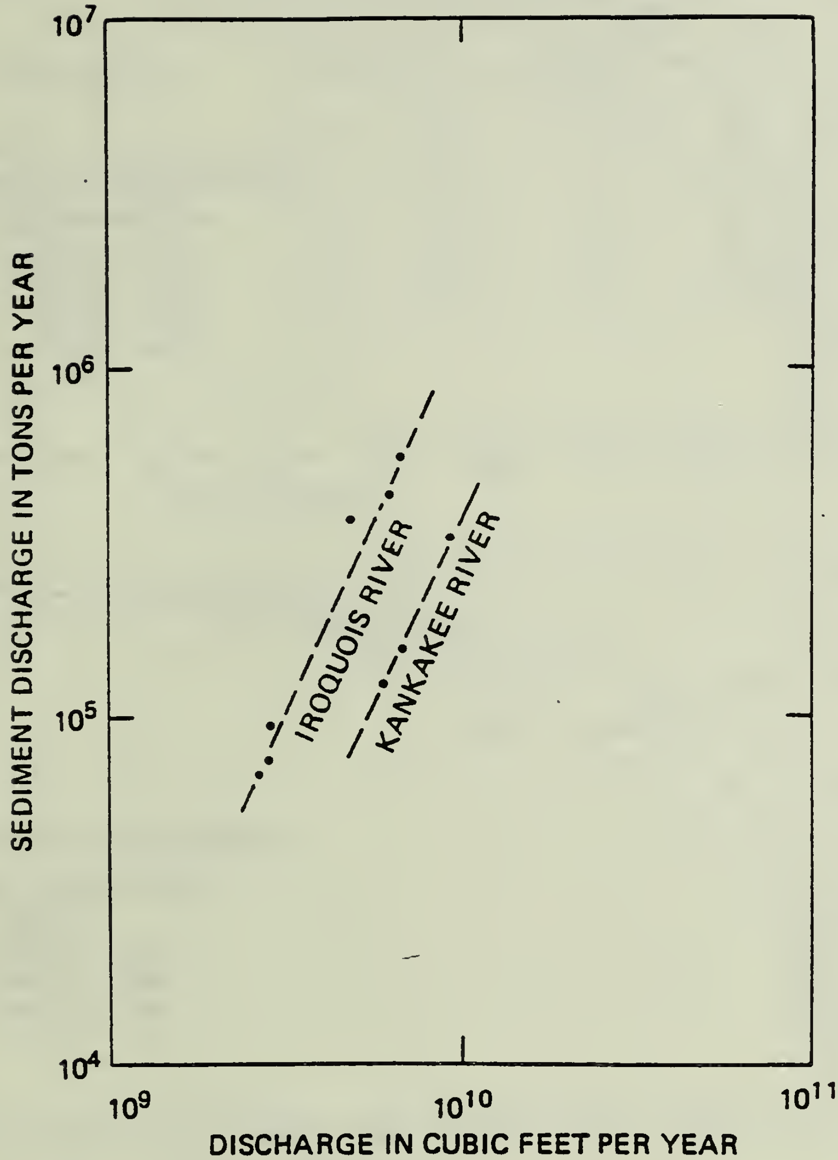


Figure 9. Relationships between annual sediment and water discharges for the Kankakee and Iroquois Rivers

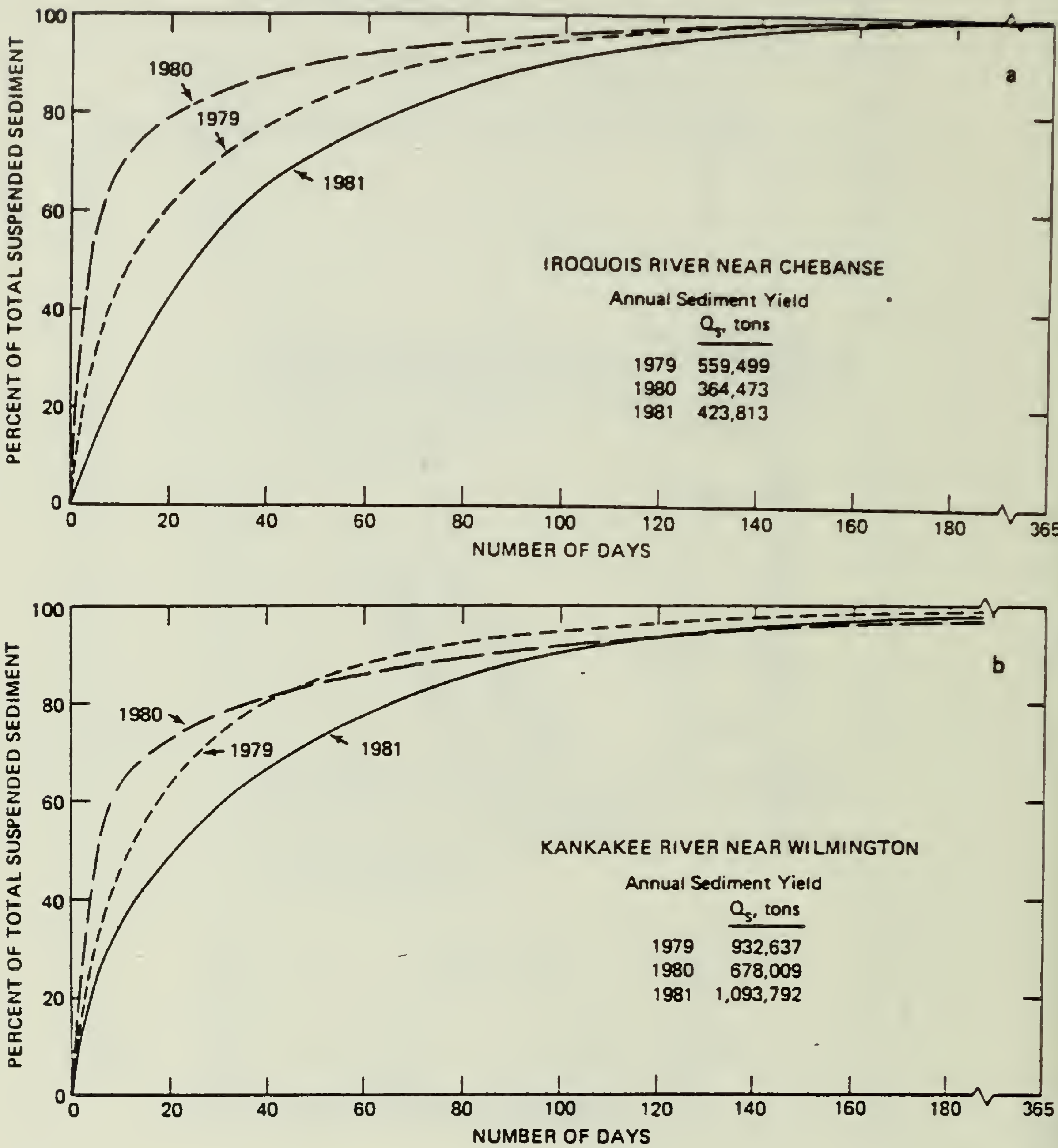


Figure 10. Percent of total sediment transported in a given number of days

Table 1. Total Water Discharge and Sediment Yield in the Kankakee River Basin

Station	Water year 1979		Water year 1980		Water year 1981		Average yearly sediment yield, Q_s (tons)
	Q_w (10^9 cu ft)	Q_s (tons)	Q_w (10^9 cu ft)	Q_s (tons)	Q_w (10^9 cu ft)	Q_s (tons)	
Momence	68.48	157,673	59.47	121,300	91.12	323,720	200,898
Iroquois	18.48	93,131	16.47	69,298	18.97	76,729	79,719
Chebanse	67.61	559,499	47.39	364,482	62.05	423,813	449,265
Wilmington	160.00	932,637	125.10	678,075	187.90	1,093,792	901,501

Note: Q_w = water discharge; Q_s = sediment load

USE OF COMPUTER PROGRAMS IN EROSION CONTROL DECISION MAKING

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The title of this paper is perhaps a bit more ambitious than its actual contents. Since the title was assigned several months before the paper was written, the author has taken the liberty of distilling the topic to a somewhat narrower scope, namely that of describing one specific computer model developed at the University of Illinois' Department of Agricultural Economics. The model is known as SOILEC, which is an acronym for a SOIL conservation EConomics simulator. It is one of only three models (at least to the knowledge of this author) which have been designed to analyze the economic and physical impacts of soil conservation methods on a rather broad range of soils and locations. The other two models — EPIC (Williams, et. al.) and COSTS (Raitt) — were recently described along with SOILEC (Eleveld, et. al.) in the Journal of Soil and Water Conservation.

The development of SOILEC began with a project funded by the Economic Research Service (ERS) of the USDA which was designed to evaluate the feasibility of using conservation incentive contracts to induce farmers to adopt conservation practices on their farms. During the course of this research it became apparent that there was a need, both on the part of farmers and policy makers, for a tool which would present the economic tradeoffs involved in choosing one particular set of cropping management practices over the wide array of alternatives which could also be chosen and which might have more favorable attributes from a conservation viewpoint.

Farmers would be interested for obvious reasons. Such a model would allow them to choose the profit maximizing management system which is consistent with their other, nonpecuniary goals. For policy purposed, the model could be used to estimate the amount of cost share payment or other incentive needed to induce farmers to switch from current practices to those which would achieve desired soil loss reductions. The Soil Conservation Service (SCS) saw promise in this line of research for their field staff's needs in drawing up conservation plans with their farmer clientele. Consequently, they have been funding further development of the model and they plan to implement its use on a rather broad scale through their area and district offices.

How SOILEC Works

Figure 1 is a schematic diagram which summarizes the physical and economic relationships included in the SOILEC model. Economic relationships are shown by the heavy lines while primarily physical relationships are shown by light connecting lines. At the core of the SOILEC model is the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith which calculates average

annual sheet and rill erosion. For each soil type included in the input data a relationship must be specified between topsoil loss and reductions in crop productivity. For applications made to date this topsoil depth/crop yield relationship has been based on yield indices for four discrete erosion phases: (1), uneroded or no topsoil loss; (2), moderately eroded or four inches of A horizon remaining; (3), severely eroded or no A horizon remaining; and (4), very severely eroded or topsoil eroded to the underlying material. In Illinois, estimates have been made for percentage adjustments to the basic soil type productivity indices as shown in Table 1 (Fehrenbacher, et.al.). Linear interpolations are made for crop yields between these four yield estimates. Production cost estimates for the various crop rotations and tillage systems in the model can be developed in a wide variety of ways. Several versions of the Oklahoma State University enterprise budget generator are available for this purpose including ERS's FEDS system and SCS's CBS system. The way in which production costs increase with diminishing topsoil depth must also be specified. A promising methodology for doing this has been reported for the Des Moines River Basin in Iowa (USDA) which appears to be applicable for other areas as well.

Users of SOILEC may choose crop management systems for combinations of crop rotations, tillage practices, and physical erosion control practices such as terracing, contour cultivation and strip cropping (and various combinations of these three physical control practices). The number of such alternatives is limited only by the data available in the current data input file. Users may specify rotations and tillage systems as their needs for a particular region dictate. The model then simulates the soil loss and the economic outcomes for each of these crop management systems over a one-year or a long run planning horizon. Normally a long run planning horizon is specified to be in the range of from 20 to 50 years into the future.

The simulation model calculates annual net income per acre for each management system. These annual net incomes are then discounted by a user-specified discounting rate (up to four rates may be specified for comparative purposes) and summed to their present value at the beginning of the planning horizon. The sum is then converted to an equivalent, perpetual annuity that would have the same present value as the income provided by that management system. Included in this annuity is an estimate of the salvage value of the land at the end of the planning horizon. Since actual net income varies through time for each management system, the annuity comparison has the advantage that each system can be compared on the basis of a constant annual amount. After the user has specified which management system is to be considered as the base, a cost for shifting to another system is calculated as the loss or gain in annual net income per acre.

Input Data Required by SOILEC

In its current state the model requires that the user build or assemble an input data file that contains a variety of physical and economic information:

1. Commodity prices for all crops included in rotations. Because these are assumed constant for the entire long run planning horizon, the model results are considered to be net of inflation.

2. Rates of technological change in production specified separately for each crop.

3. Interest rates for use in discounting future net income to the present. These are also considered to be "real" or net of inflation.

4. Rates of crop residue production for each crop.

5. Yield adjustments from the base indices for each combination of tillage system and commodity.

6. A variety of technical data on mechanical control practices.

7. The C factors to be used in the USLE for each crop rotation at various rates of residue remaining on the soil after planting.

8. Annual costs of production for each crop rotation included in the data file.

9. A variety of specific location and soil type characteristics for each distinct soil resource area to be analyzed. These generally correspond to the remaining factors for the USLE.

This list is not exhaustive but it should indicate to the reader that these data requirements are not inconsequential. However, much of this data must be collected anyway for an adequate job of conservation planning, and much of it is readily available in SCS and Cooperative Extension Service (CES) offices, where much of the conservation planning will be conducted.

Model Outputs

The SOILEC model provides the user with the option of choosing several different tabular and graphic outputs, some of which are shown in this paper. Table 2 shows the detailed physical results that can be generated by the model. When this option is chosen, a separate table like this one is produced for each and every management system on each soil type chosen for analysis by the user. Obviously, users should be somewhat judicious in their choices in order to avoid generating a mountain of computer output.

The crop management system and soil type being analyzed are shown at the top of Table 2. In this example the system is a corn - soybean rotation (CS) using a conventional fall plow (FPL) tillage system with no contour cultivation (VERT). The soil used for this example is Miami, a soil common in Indiana and several other Corn Belt states. The amount of annual soil loss is shown in both tons and inches of topsoil in the first two columns.

The next three columns show the remaining topsoil depth in the A and B horizons and in total. In this example the reader can see that the most productive layer of topsoil, the A horizon, is completely eroded in only 20 years. The next three columns show the commodity yields as they change through time as a result of progressive soil erosion. Since yield estimates differed for continuous corn (CCOR) and corn grown after soybeans in rotation (CAFS), two separate corn crops were specified in this data set. The third crop shown is soybeans (SOYB). Up to ten separate crops can be included in a particular data set although use of that many crops would obviously require a continuation page to this table.

The same information contained in Table 2 can also be generated in graphic form as shown in Figures 2 and 3. Figure 2 shows the topsoil depths through time while Figure 3 shows how the commodity yields decrease. These two graphs were produced using a planning horizon of 50 years rather than the 30 year period used in the tables. Since a separate copy of each of these graphs is produced for each soil type/management system combination, the same caveat about mountains of paper applies that was mentioned in connection with Table 2.

The next output form, shown in Table 3, can again be selected at the user's option. This table shows the annual net income calculated by the model. The first four columns show annual net income discounted to a present value with each of (up to) four discount rates selected by the user. If one of the discount rates selected by the user is 0.0 percent, then the corresponding column will give undiscounted net incomes. The rightmost four columns are merely a cumulative addition of the annual net income figures given in the leftmost four columns. Note that the column with a zero discount rate has an infinite sum. This is due to the inclusion of the salvage value of the land at the end of the planning horizon. The assumption made in this regard is that the net income realized in the last year can be maintained for an infinite time period. Since the salvage value of the land is a simple income capitalization formula, if the discount rate is zero, it goes to infinity. For the non zero discount rates, the difference between the total figure and the cumulative discounted net income in the last year is the discounted salvage value of the land (discounted to the beginning of the planning horizon). Again, if the user specifies this output option, the potential for producing mountains of computer output exists.

A final output option is available which summarizes the information contained in the preceding figures and tables. Table 4 is a summary table which condenses both the physical (erosion) and the economic results for all the management systems chosen for analysis. If this is the only output option chosen the user will get only one table for each combination of soil type and discount rate chosen for analysis. Since most farm planners would use their real opportunity cost for investments as the discount rate, they would only need to look at one of these summary tables for each soil type they wished to analyze. The heading or top part of Table 4 states which soil type or region is being analyzed and stipulates which crop management system was chosen by

the user to represent the base system. For most farm planning applications the base system would likely be the existing system but this is not a necessity. The significance of choosing a base is that all other systems are compared to this system in the lower part of the table.

In this example the base system is the same one used for the detailed physical and financial tables and graphs earlier, namely a continuous corn rotation, with conventional fall plowing in a vertical or non contoured direction. The results for the base system are presented in line 1 of Table 4. Reading across, the abbreviations for the rotation and tillage system are given and the ones or zeros in the next four columns indicate, respectively, the use or non use of the four mechanical control practices for which the abbreviations are explained at the bottom of the table. Note that several ones might appear in these four columns, indicating that a combination of mechanical control practices are being used. The next column gives the remaining annual soil loss figure as calculated by the USLE. Actually, this is an average of the soil losses calculated for each year during the planning horizon. The figure in the next column for the base system is the annual net income annuity, thus the title, Net Revenue Change per Unit Area, is something of a misnomer for the base system. It is, however, appropriate for all the other systems, as will be pointed out later. The figures in the next two columns should always be zeros for the base system since they are comparisons between the base and alternatives.

All of the remaining lines in the table show comparisons between the alternative system on a given line to the base system on line 1. Let us look at line 2 as an example. The rotation/tillage and mechanical control practice notation remains the same as line 1, as does the next column, Remaining Annual Soil Loss. The next column, however, now gives the change in net revenue for choosing the system on line 2 as opposed to the base system. If this figure is positive, as it is in this example, it indicates that the alternative on that line is more profitable than the system which was chosen as the base. In this instance, a corn - soybean rotation using the Till Plant system of cultivation (TPLT, otherwise know as Ridge Till) earns a net revenue annuity which is $57.90/ac. higher per year than does the base system. The next column shows the reduction in annual soil loss obtained by using this system rather than the base. Finally, the last column presents the cost of changing from the base to the alternative system in terms of income lost per ton of erosion reduction. Negative numbers here are good in that a negative cost is a benefit. Note that whenever the reduction in soil loss is negative (an increase in soil loss), then the cost per ton of erosion reduction becomes infinite.

The alternative systems in Table 4 are ranked according to the net revenue changes per unit of area with the best systems at the top. Alternatively, the user may choose to rank the alternatives based on the reduction in soil loss column or the annual cost per unit of soil loss reduction column. The ranking shown here seems to make the most sense for farm planning purposes since farmers would most likely wish to maximize their income, perhaps with

some soil loss constraint. Policy makers might, however, wish to use the latter two ranking alternatives, especially if they had a target of some specified erosion reduction per acre or a goal of reducing erosion by a certain number of tons within a region and wanted to target assistance payments to the most efficient practices in achieving this goal.

How might a farmer use the information contain in Table 4? Let us suppose he is currently operating with the base system and wants to reduce soil erosion if it doesn't sacrifice profitability. Obviously, he would move to the system given on line 2, the profit maximizing system, since it almost halves erosion while simultaneously increasing net income by $57.90/ac./yr. What if he wanted to get down to T-value which is less than 5 tons of erosion annually? He could do this by changing to the system on line 26 -- a continuous corn, no till system with contouring and terracing at a net revenue cost of only $2.61/ac. After seeing this table however, he would know that the real loss is the difference between system 2 and system 27 (the difference between $57.90 and -$2.61) which amounts to a loss of $60.51/ac. annually. Often intermediate solutions appear in the table which made attractive compromises. For example, system 6 -- continuous corn with no till -- reduces erosion to about eight tons per acre and its annual net revenue is only $10.75 less than the most profitable one and $47.15 more profitable than the base system. In the short run it has other advantages over the system which achieves T-value in that it does not require the heavy initial investment in terrace construction.

Planned Improvements

Several enhancements and improvements are planned to be made to SOILEC under the terms of a cooperative agreement during the coming year between SCS and the University of Illinois. Because the model considers only sheet and rill erosion, it currently has less than nationwide applicability. A subroutine to include wind erosion will be added to made the model more useful in the Great Plains and Western States. The addition of a schematic output in tree diagram form, similar to the COSTS model (Raitt), will permit tracing the cumulative effects of adding various conservation practices. Other minor technical changes to make the model more "user friendly" are also planned.

Implementation and Application

The version of the model which is illustrated in this paper is already in the hands of SCS. They are in the process of making it operational on their Washington, D.C. mainframe computer system during the current fiscal year. The model will be accessible from SCS state offices, and area and district offices that have the necessary computer hardware. The model's computer code is also being adapted to run on an IBM personal computer.

As mentioned at the beginning of this paper, the data requirements of SOILEC are somewhat detailed and technical in nature so it is unlikely that farmers will soon be able to use this program on their own. Rather, it is envisioned

that the model will replace the hand calculations that are often done by technical specialists, such as SCS district conservationists and extension farm advisors, as they make conservation plans with their farmer clientele. The advantages that this program affords over present methods include: (1), time savings; (2), the ability to consider a much broader range of conservation alternatives; and (3), the ability to consider the long run impacts of soil conservation on crop yields and production costs in making a choice between systems. Eventually, as the data sets required to run the model are compiled by state and local SCS and CES offices, the model may be made available to individual farmers to run on their own microcomputers at home.

For policy making purposes, the program may be useful at a variety of levels in targeting assistance payments to crop management systems that are the most cost efficient in reducing soil erosion and in determining the levels of payments necessary to induce desired conservation actions by farm operators.

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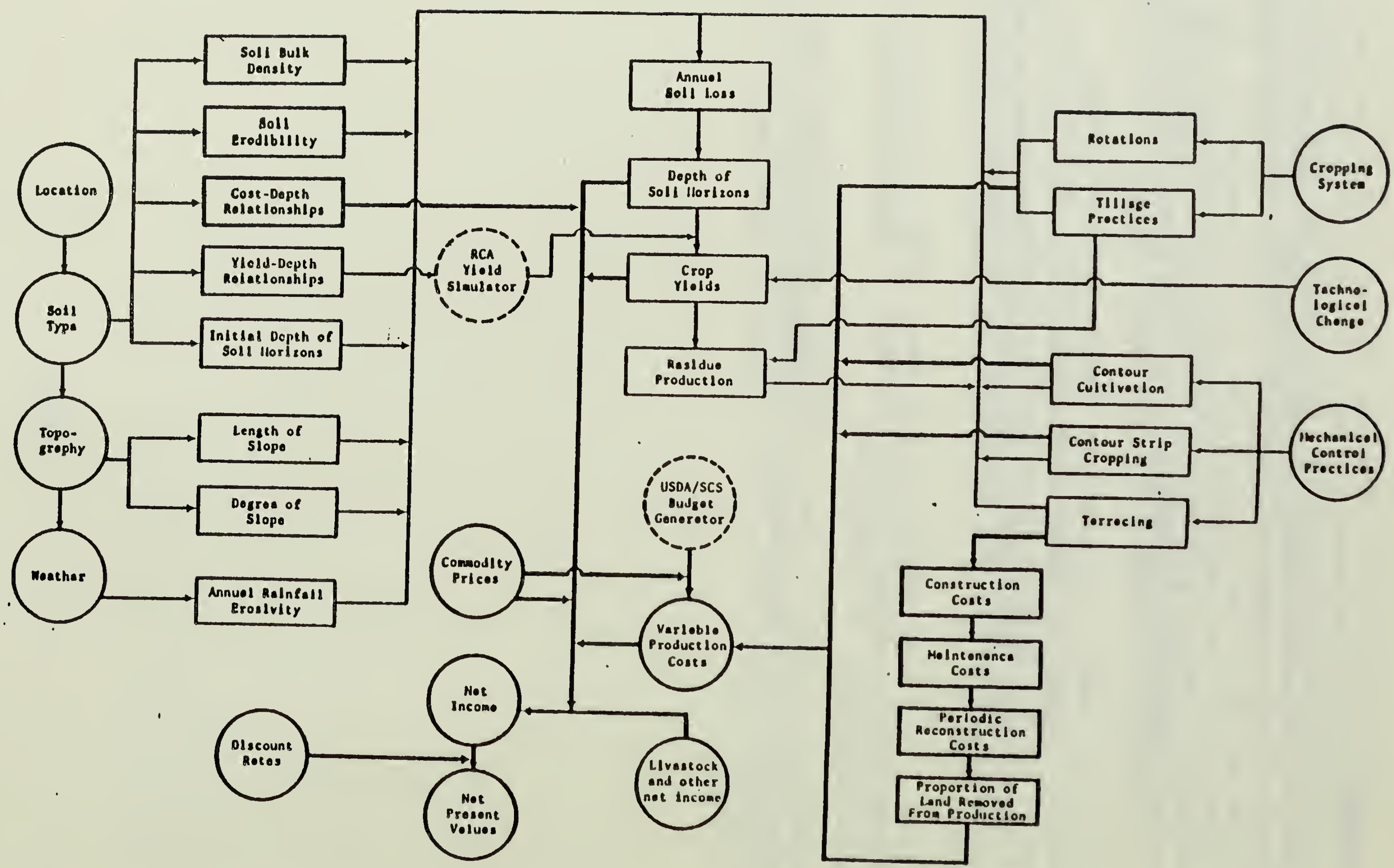
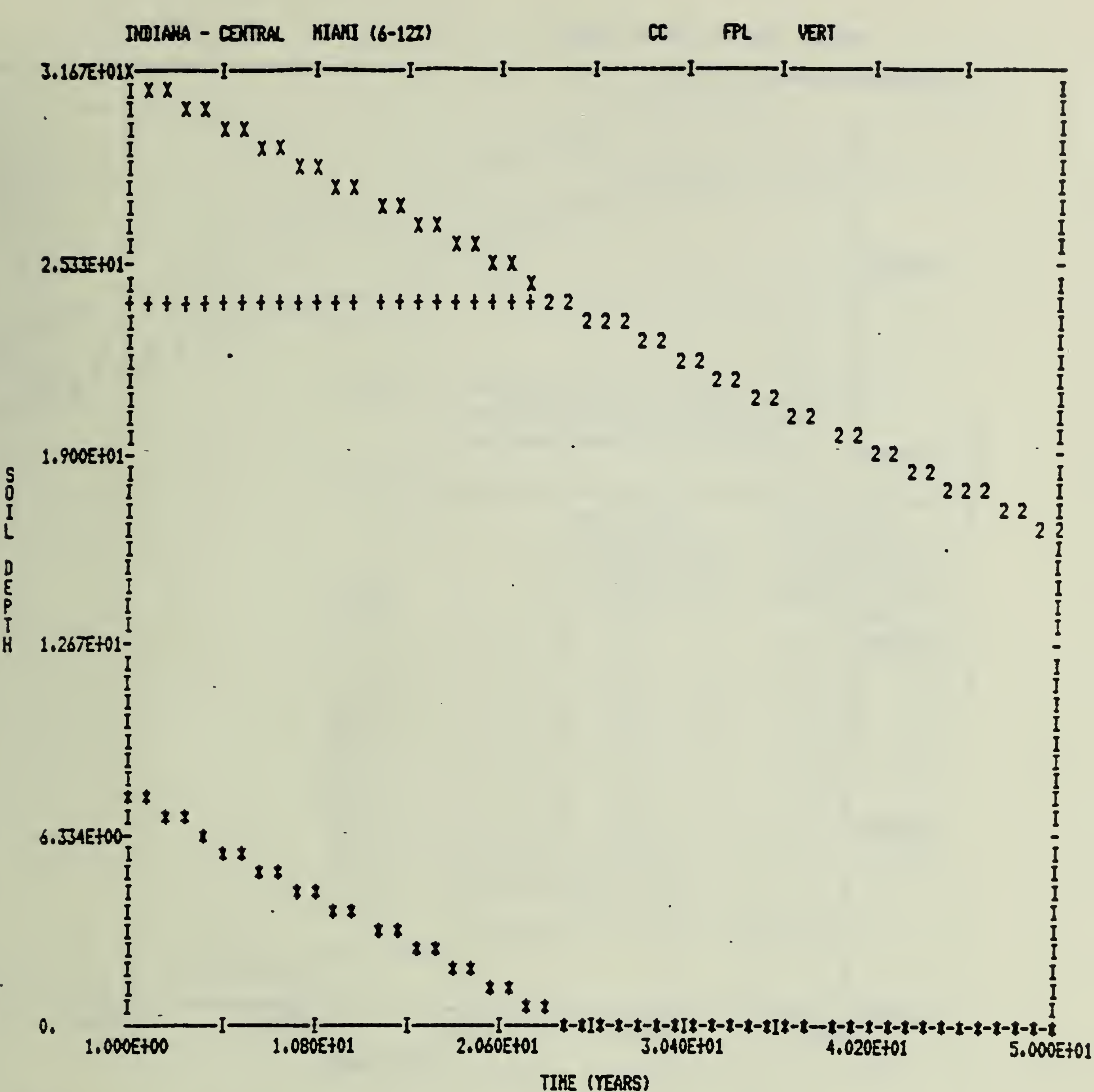
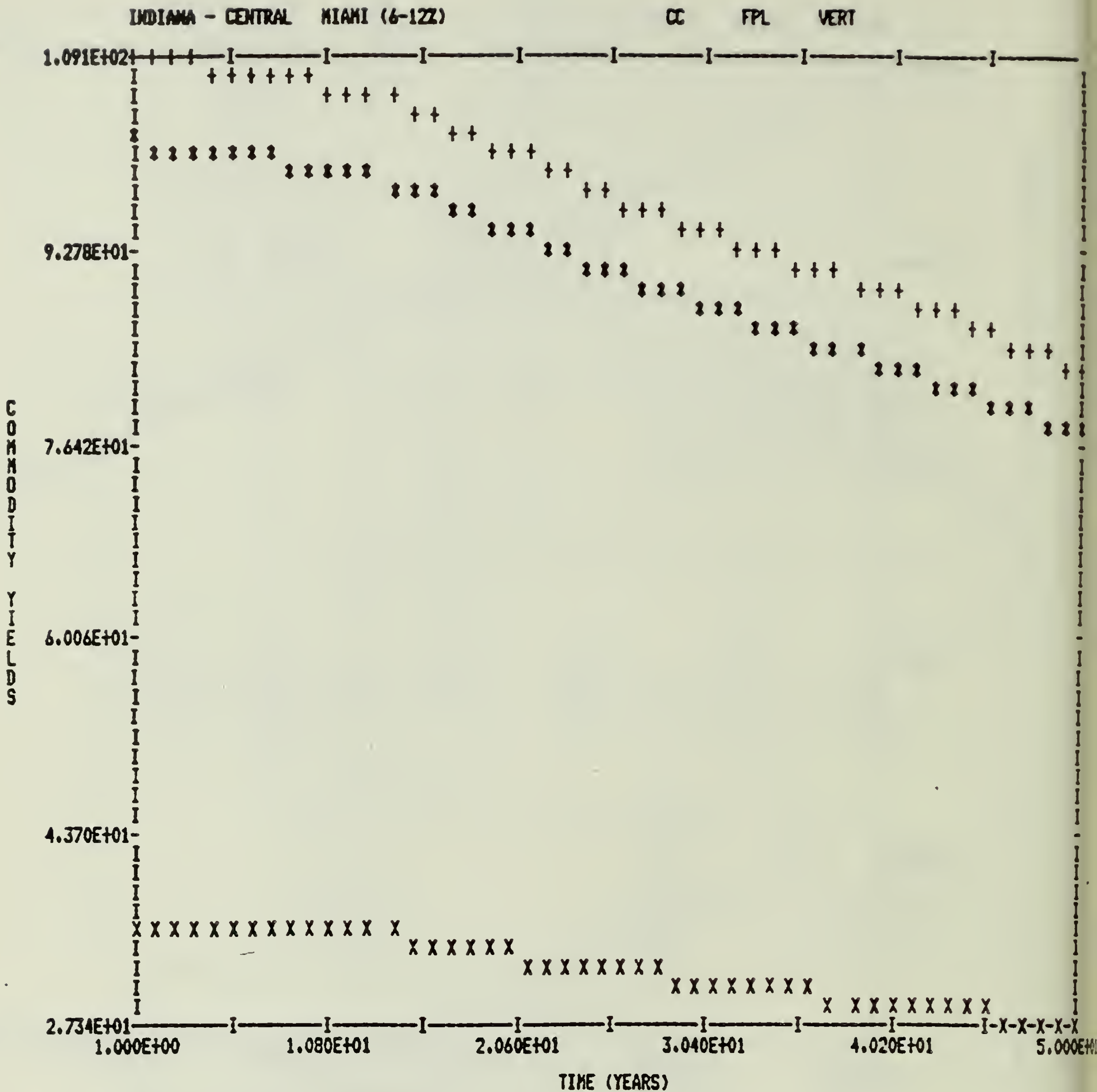


Figure 1. Summary of Relationships in the Soil Conservation Economics Model (SOILEC)



‡ CORRESPONDS TO HORIZON A (IN)
+ CORRESPONDS TO HORIZON B (IN)
X CORRESPONDS TO TOTAL (IN)
2 CORRESPONDS TO 2 COINCIDENCES

Figure 2. SOILEC Graph Showing Depth of A and B Horizons and Total Topsoil Depth Over the Planning Horizon



*	CORRESPONDS TO	CCOR	(BU/AC)
+	CORRESPONDS TO	CAFS	(BU/AC)
X	CORRESPONDS TO	SOYB	(BU/AC)
2	CORRESPONDS TO	2 COINCIDENCES	

Figure 3. SOILEC Graph Showing Commodity Yields Over the Planning Horizon

Table 1. Percentage Adjustments in Yields for Common Slope Groups and Various Erosion Conditions

Slope	High management, favorable subsoil			High management, unfavorable subsoil		
	Un-eroded	Moderate erosion	Severe erosion	Un-eroded	Moderate erosion	Severe erosion
(percent)		(percent)			(percent)	
0–2	100	97	90	100	95	80
2–5	99	96	89	99	94	79
5–10	97	94	87	96	91	76
10–15	93	90	83	91	86	71
15–20	87	84	77	85	80	65
20–25	80	77	70	78	73	58
25–30	71	68	61	69	64	49
30–35	60	57	50	58	53	38
35–40	52	49	42	50	45	30
45–	48	45	38	46	41	26

Source: Fehrenbacher, et. al.

Table 2.
LONG-RUN
PHYSICAL ANALYSIS FOR REGION-SOIL: INDIANA - CENTRAL MIAMI (6-12%)
ROTATION-TILLAGE: CC FPL
MECHANICAL CONTROL PRACTICE(S): VERT

YEAR	TOTAL SOIL LOSS		SOIL DEPTH A	B	TOTAL	COMMODITY YIELDS CCOR	CAFS	SOYB
	(TN/AC)	(IN.)	(IN.)	(IN.)	(IN.)	(BU/AC)	(BU/AC)	(BU/AC)
0	0.00	0.00	8.00	24.00	32.00	102.00	109.14	36.00
1	.51.57	.33	7.67	24.00	31.67	102.00	109.14	36.00
2	51.57	.33	7.34	24.00	31.34	101.75	108.87	35.92
3	51.57	.33	7.00	24.00	31.00	101.50	108.61	35.83
4	51.57	.33	6.67	24.00	30.67	101.25	108.34	35.75
5	51.57	.33	6.34	24.00	30.34	101.00	108.07	35.67
6	51.57	.33	6.01	24.00	30.01	100.75	107.81	35.58
7	51.57	.33	5.67	24.00	29.67	100.51	107.54	35.50
8	51.57	.33	5.34	24.00	29.34	100.26	107.27	35.42
9	51.57	.33	5.01	24.00	29.01	100.01	107.01	35.34
10	51.57	.33	4.68	24.00	28.68	99.76	106.74	35.25
11	51.57	.33	4.35	24.00	28.35	99.51	106.47	35.17
12	51.57	.33	4.01	24.00	28.01	99.26	106.21	35.09
13	51.57	.33	3.68	24.00	27.68	99.01	105.94	35.00
14	51.57	.33	3.35	24.00	27.35	98.36	105.25	34.76
15	51.57	.33	3.02	24.00	27.02	97.70	104.54	34.51
16	51.57	.33	2.68	24.00	26.68	97.03	103.83	34.26
17	51.57	.33	2.35	24.00	26.35	96.37	103.11	34.01
18	51.57	.33	2.02	24.00	26.02	95.70	102.40	33.76
19	51.57	.33	1.69	24.00	25.69	95.04	101.69	33.52
20	51.57	.33	1.36	24.00	25.36	94.38	100.98	33.27
21	51.57	.33	1.02	24.00	25.02	93.71	100.27	33.02
22	51.57	.33	.69	24.00	24.69	93.05	99.56	32.77
23	51.57	.33	.36	24.00	24.36	92.38	98.85	32.52
24	51.57	.33	.03	24.00	24.03	91.72	98.14	32.27
25	51.57	.33	0.00	23.72	23.72	91.05	97.43	32.02
26	51.57	.30	0.00	23.43	23.43	90.51	96.84	31.83
27	51.57	.30	0.00	23.13	23.13	89.97	96.27	31.64
28	51.57	.30	0.00	22.83	22.83	89.43	95.69	31.45
29	51.57	.30	0.00	22.53	22.53	88.90	95.12	31.27
30	51.57	.30	0.00	22.23	22.23	88.36	94.55	31.08
MEAN	51.57	.33	3.08	23.80	26.87	96.34	103.08	33.98

FIRST YEAR VALUES: R = 180.00 K = .37 LS = 1.936 C = .400 P = 1.000

FOR TILLAGE SYSTEM FPL YIELD ADJUSTMENTS ARE:
0.0 7.0 0.0

Table 3.
LONG-RUN
FINANCIAL ANALYSIS FOR REGION-SOIL: INDIANA - CENTRAL MIAMI (6-12%)

NET PRESENT VALUES FOR ROTATION-TILLAGE SYSTEM: CC FPL
MECHANICAL CONTROL PRACTICE(S): VERT

YEAR	NET PRESENT VALUES ($/AC) AT DISCOUNT RATES (%) - 0.00	4.00	8.00	10.00	CUMULATIVE NET PRESENT VALUES ($/AC) AT DISCOUNT RATES (%) - 0.00	4.00	8.00	10.00
1	93.00	89.42	86.11	84.55	93.00	89.42	86.11	84.55
2	91.84	84.91	78.74	75.90	184.84	174.33	164.85	160.44
3	90.67	80.61	71.98	68.13	275.51	254.94	236.83	228.57
4	89.51	76.51	65.79	61.14	365.02	331.46	302.62	289.71
5	88.35	72.62	60.13	54.86	453.37	404.07	362.75	344.56
6	87.19	68.90	54.94	49.21	540.56	472.98	417.69	393.78
7	86.02	65.37	50.19	44.14	626.58	538.35	467.89	437.92
8	84.86	62.01	45.85	39.59	711.44	600.35	513.73	477.51
9	83.70	58.81	41.87	35.50	795.14	659.16	555.60	513.01
10	82.54	55.76	38.23	31.82	877.68	714.92	593.83	544.83
11	81.37	52.86	34.90	28.52	959.05	767.78	628.73	573.35
12	80.21	50.10	31.85	25.56	1039.26	817.87	660.58	598.91
13	79.05	47.47	29.07	22.90	1118.30	865.35	689.65	621.80
14	76.81	44.35	26.15	20.23	1195.11	909.70	715.80	642.03
15	74.52	41.38	23.49	17.84	1269.64	951.08	739.29	659.87
16	72.24	38.57	21.09	15.72	1341.88	989.65	760.38	675.59
17	69.96	35.91	18.91	13.84	1411.83	1025.57	779.29	689.43
18	67.67	33.40	16.93	12.17	1479.50	1058.97	796.22	701.60
19	65.39	31.04	15.15	10.69	1544.89	1090.01	811.37	712.29
20	63.10	28.80	13.54	9.38	1608.00	1118.81	824.91	721.67
21	60.82	26.69	12.08	8.22	1668.82	1145.50	836.99	729.89
22	58.54	24.70	10.77	7.19	1727.35	1170.19	847.76	737.08
23	56.25	22.82	9.58	6.28	1783.60	1193.02	857.34	743.36
24	53.97	21.05	8.51	5.48	1837.57	1214.07	865.85	748.84
25	51.68	19.39	7.55	4.77	1889.25	1233.46	873.40	753.61
26	49.95	18.01	6.75	4.19	1939.20	1251.47	880.15	757.80
27	48.25	16.74	6.04	3.68	1987.45	1268.21	886.19	761.49
28	46.56	15.53	5.40	3.23	2034.02	1283.74	891.59	764.71
29	44.87	14.39	4.82	2.83	2078.89	1298.13	896.40	767.54
30	43.18	13.31	4.29	2.47	2122.08	1311.44	900.70	770.02
TOTAL					99999.99	1644.30	954.34	794.77

TOTAL INCLUDES ALLOWANCE FOR VALUE OF LAND AT END OF PERIOD
(99999.99 = INFINITE)

Table 4.
LONG-RUN
FINANCIAL ANALYSIS FOR REGION-SOIL: INDIANA - CENTRAL MIAMI (6-12%)

REDUCTION IN EROSION COMPARED WITH BASE ROTATION-TILLAGE SYSTEMS: CC FPL
AND BASE MECHANICAL CONTROL PRACTICE(S): VERT
DISCOUNT RATE (%): 8.00

NO.	ROTATION-TILLAGE SYSTEM		MECHANICAL CONTROL PRACTICES VERT	CONT	STRP	TERR	REMAINING ANNUAL SOIL LOSS	NET REV. CHNG PER UNIT AREA	REDUCTION IN ANNUAL SOIL LOSS	ANN. CST PER UNIT REDUCTN
							(TON/ACRE)	($/ACRE)	(TON/ACRE)	($/TON)
1	CC	FPL	1	0	0	0	51.572	76.35	0.000	0.00
2	CS	TPLT	1	0	0	0	28.365	57.90	23.207	-2.50
3	CS	NT	1	0	0	0	14.182	55.18	37.390	-1.48
4	CC	TPLT	1	0	0	0	15.472	48.11	36.100	-1.33
5	CS	TPLT	0	1	0	0	28.365	47.90	23.207	-2.06
6	CC	NT	1	0	0	0	7.865	47.15	43.707	-1.08
7	CS	NT	0	1	0	0	14.182	45.18	37.390	-1.21
8	CC	TPLT	0	1	0	0	15.472	38.11	36.100	-1.06
9	CS	SDSK	1	0	0	0	41.258	37.18	10.314	-3.60
10	CC	NT	0	1	0	0	7.865	37.15	43.707	-.85
11	CS	FCH	1	0	0	0	41.258	34.18	10.314	-3.31
12	CS	SDSK	0	1	0	0	41.258	27.18	10.314	-2.64
13	CC	FCH	1	0	0	0	25.786	25.89	25.786	-1.00
14	CS	FCH	0	1	0	0	41.258	24.18	10.314	-2.34
15	CC	SDSK	1	0	0	0	39.968	21.33	11.604	-1.84
16	CS	SPL	1	0	0	0	55.440	19.72	-3.868	99999.99
17	CC	FCH	0	1	0	0	25.786	15.89	25.786	-.62
18	CC	SDSK	0	1	0	0	39.968	11.33	11.604	-.98
19	CS	FPL	1	0	0	0	60.597	11.05	-9.025	99999.99
20	CS	TPLT	0	1	0	1	12.034	11.05	39.538	-.28
21	CS	SPL	0	1	0	0	55.440	9.72	-3.868	99999.99
22	CC	SPL	1	0	0	0	47.704	8.20	3.868	-2.12
23	CS	NT	0	1	0	1	6.017	5.85	45.555	-.13
24	CS	FPL	0	1	0	0	60.597	1.05	-9.025	99999.99
25	CC	TPLT	0	1	0	1	6.564	-.58	45.008	.01
26	CC	SPL	0	1	0	0	47.704	-1.80	3.868	.46
27	CC	NT	0	1	0	1	3.337	-2.61	48.235	.05
28	CS	SDSK	0	1	0	1	17.504	-5.31	34.068	.16
29	CS	FCH	0	1	0	1	17.504	-8.16	34.068	.24
30	CC	FPL	0	1	0	0	51.572	-10.00	0.000	99999.99
31	CS	SPL	0	1	0	1	23.521	-18.27	28.051	.65
32	CC	FCH	0	1	0	1	10.940	-19.94	40.632	.49
33	CC	SDSK	0	1	0	1	16.957	-20.47	34.615	.59
34	CS	FPL	0	1	0	1	25.709	-25.87	25.863	1.00
35	CC	SPL	0	1	0	1	20.239	-30.78	31.333	.98
36	CC	FPL	0	1	0	1	21.880	-37.99	29.692	1.28

VERT = UP-AND-DOWN-SLOPE (VERTICAL) CULTIVATION
CONT = CONTOUR CULTIVATION
STRP = CONTOUR STRIP CROPPING
TERR = TERRACING
99999.99 = INFINITE

TARGETING OF USDA RESOURCES

John E. Eckes, State Conservationist
UDSA-Soil Conservation Service

The idea of targeting funds to areas of critical resource problems has been with us for a long time. Soil Conservation Service (SCS) managers, with districts, have been setting priorites for the use of their limited resources. We have long recognized the need to adjust staffing patterns to meet changing needs and concerns. Congress, too, has been targeting for years. The Great Plains Program is targeted to parts of 10 states. The Watershed Program is targeted to areas with chronic flooding problems. The Rural Clean Water Program is available in only selected areas. There are numerous other examples of targeting where we have not yet applied the term "targeting".

As USDA began carrying out the provisions of the Resource Conservation Act (RCA) of 1977, it became apparent that all the natural resource concerns could not be addressed with the same intensity. The resource problems facing the Nation were of such a variety and magnitude that priorities needed to be set. Through public participation, citizens across the Nation told us that soil erosion was their major concern. They also had a high concern for upstream damage from floods and a need to conserve water. It became obvious that USDA needed to redirect its resources to more fully address these major concerns. One tool to do this was targeting...<u>the process of directing certain funds to be used for a specific purpose within a designated area</u>. The RCA Program calls for targeting an additional five percent of the available funds now used for technical and financial assistance annually, until the targeting total reaches 25 percent. Last year SCS targeted five percent ($12.5 million) of conservation technical assistance funds to 31 states for water conservation and erosion control. The Agricultural Stabilization and Conservation Service (ASCS) is targeting ACP funds to most of these same areas.

<u>Purpose and Objectives</u>

The <u>purpose</u> of national targeting is to emphasize the protection of the Nation's agricultural production capability through increased erosion control and water conservation. <u>Targeting is designed to accelerate conservation treatment in areas that have more critical and persistent erosion and water problems</u>. Targeting differs from ongoing CTA efforts in that it singles out a specific type and degree of resource problem in accord with local and state priorities. <u>Targeting will demonstrate that a concentrated conservation effort can be effective in reducing major problems in a cost-effective manner</u>. It also supplements the ongoing conservation efforts by identifying national conservation priorities. <u>Rationale for Selection of Targeted Areas</u>

Our rationale for selecting targeted areas is based on four basic considerations:

- Severity and extent of the problem.
- Effect on agricultural productivity and offsite damages.
- Expected results.
- Local interest and willingness to support the effort.

The severity and extent of the problem under consideration identified the most critical problems. For example, if soil erosion on cropland is the problem, the annual rate of soil loss in tons per acre and the extent of the problem in terms of the acres of cropland affected was considered. First and foremost is there a problem?

The second consideration was the effect of the problem on productivity and offsite damages. In some cases the soil loss may not be as severe as in other areas of the county, but because these soils are shallow, even a relatively small amount of soil loss adversely affects productivity. We also considered the impact of soil loss on sedimentation such as road ditches, streams, lakes, and reservoirs.

The third consideration and an important one, what kind of success can be expected? We considered the solutions available. If the conservation system needed was high cost and farmers relied solely on cost-share funds for implementation, then additional technical assistance alone was not the answer. If, however, low cost conservation measures such as contouring, conservation tillage, land use adjustments, and others could be implemented, additional technical assistance could be effective in resolving the problem. We are concerned about the possibility of over saturating an area with technical assistance where the need for financial assistance is the road block.

The fourth consideration was for the type of conservation program currently being carried out in the area. Consideration was given to the attitude of local people and their interest in the problem area. Our philosophy is to accelerate a local effort rather than initiate the effort.

Summary

To accelerate a program of soil and water conservation in any area of the country, but specifically the designated target areas, goes well beyond just adding more technical assistance and funds. Dr. Peter Nowak at Iowa State University conducted a special study in several Midwest states to find out why farmers are not applying conservation practices at a faster rate.

In talking to nearly 700 farmers it was found that:

- Many farmers are confused about the various conservation-related agencies as well as about the services each provides;

- Farmers want more assistance in identifying and solving soil erosion problems on their own farms;

- Official sources of conservation information are not as widely used or as influential as many believe they should be;

- Many farmers aren't sure what is involved with an SCS Conservation Plan; and

- Most want to know more about how different conservation practices will affect their operations as well as what's involved with receiving government assistance for using these practices.

It is rather obvious then to me that "targeting" USDA resources requires careful planning and certainly a "team" approach at all levels if we are to solve some of the persistent erosion, water quality, and flood problems occuring on our agricultural land today.

STATUS OF COMPLAINTS IN THE EROSION AND SEDIMENT CONTROL LAW

Gary Wood, Bureau Chief
Division of Natural Resources
Illinois Department of Agriculture

I have received many questions from people regarding the number of complaints Districts have received. But, what does the number really mean? If there is a small number, does it mean the program is a failure? Or, if I tell you there is a high number of complaints, does that mean it's a success? I feel it is not important whether I tell you it's 1 or 1,000 — what is important is the success of each complaint filed.

The system was not developed to break any records or to solve the soil erosion problem. It was developed to allow a means for an individual to complain about a landowner who has excessive soil erosion. Before I provide you with the status of complaints, I would like to explain the complaint process.

The complaint process began January 1, 1983. When an individual sites an erosion problem, he can file a compliant with the Soil and Water Conservation District. The District then notifies the alleged violator that a complaint has been filed and District personnel perform an investigation. If the alleged violator is not in compliance with District standards, the landowner has one year to develop a schedule for compliance. A schedule for compliance is simply a conservation plan whereby the landowner develops a schedule to solve his erosion problem. If he does not develop this schedule within one year, the Soil and Water Conservation District will hold a public hearing. At this public hearing, it is determined why the schedule for compliance has not been completed.

Now, let me give you some statistics about how far the program has progressed. Currently, 34 complaints have occurred in 24 counties in the State. Twenty-three of these complaints were filed by neighbors because of reasons such as sediment being received in their grass waterways or ponds, 5 by road commissioners because of sediment in road ditches, and 6 by other people, the majority have not been residents of the immediate area or have not been affected by sediment damage. Eighteen of the complaints have been in compliance with current standards, however, 7 of the 18 were very close to being out of compliance; 13 have been out of compliance; and 3 as of this date have not been investigated. Soil losses have ranged from 4 to 47 tons per acre per year and the acreage involved in each complaint has ranged from 3 acres to a total of 320 acres. Soil erosion complaints have been handled in varying ways. The following slide set will enable you to observe how the complaints have been handled by Soil and Water Conservation Districts. This slide set contains interviews with District board members, Resource Conservationists, and District Conservationists who tell their story about the complaints in their district (Slide Set).

The best way to determine the success of the program is that through the cooperation of the landowners District personnel have not been thrown off anyone's farm. However, there have been some unusual happenings while investigating the complaints. For example, Jo Daviess County received a thank you letter from the person who had the complaint filed against him thanking the District for bringing the soil erosion problem to his attention and that he would proceed as rapidly as possible to solve the problem. When Sangamon County District personnel went to investigate a complaint there was a vehicle stuck in mud in the middle of the road, so that landowner knew he was caught. In Knox County the farmer actually completed a schedule for compliance the next day.

What has been unique about the success of this program is that it is completely voluntary. There is no fine or punishment involved - it is simply peer pressure. And so far, Districts have had 100 percent cooperation.

EROSION AND SEDIMENTATION RESEARCH—A FOUNDATION—PAST, PRESENT, AND FUTURE

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Webster's dictionary defines research as "investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts or practical application of such new or revised theories or laws".

A key word in this definition is the word facts. We can observe many phenomena on a casual basis. Casual observation may be very misleading, however, since things aren't always what they appear to be and premature conclusions have sometimes resulted from casual observations of limited data. Research involves systematic evaluation with controls. It's not just a question of trying something and seeing what happens although this is often a part of the research. To have valid comparisons and conclusions, it is usually necessary to observe what happens if the same set of basic conditions exist but different treatments and no treatment are observed. No treatment is the condition which provides a control for comparison. To establish a true cause and effect relationship in scientific terms, systematic comparison is necessary. It is also necessary to maintain a standard of measurement precision, so that results are acceptable on a broad scale, are repeatable, and can be compared to and integrated with results from other research efforts.

Research is often classified as being applied or basic research, with basic research referring to the study of basic structure and behavior of things - physical, biological, etc. Applied research concentrates more on being able to put to practical use the facts obtained from the basic research efforts. The majority of research efforts, at least those in the agricultural sciences conducted at state Agricultural Experiment Stations tend to fall into a middle area between basic and applied, with a smaller portion which can be easily classified as either basic or applied.

Some of the basic research in the erosion and sedimentation area deals with the laws of soil formation, composition, movement, as well as the laws dealing with the characteristics of precipitation including energy, drop formation and characteristics, and other similar aspects. Applied research can build upon this basic research foundation to develop nondestructive productive use of the soil.

Trial and error can be and is sometimes used to attack the same problems, but problem solutions based on a true cause and effect relationship known through research is usually more efficient and successful. I can take a sample of muddy river water and observe that we have an erosion problem somewhere, but I wouldn't know where the erosion is occurring, how serious it is, what were the contributing factors, and how to most logically approach the problem of

getting and keeping the sediment out of the water, without the research knowledge that has built up over the years. Research knowledge is the foundation of facts referred to earlier, facts and laws proven by careful, controlled study, as opposed to casual observation and speculation with the potential influence of emotionalism or personal bias.
The knowledge developed by planned research is sequential - finding new knowledge, integrating, refining, and reintegrating. Even many farm-developed trial and error solutions build heavily on past research. For example, many of the reduced tillage practices in use would be impractical without the pest control and fertilizer technology which has resulted from studies in our agricultural research institutions.

The Beginning of the Foundation - Erosion and Sedimentation Research History

Most of the erosion and sediment research throughout history has been publicly supported. While there has been some philanthropic private support, it is a fact that the commercial potential of any research findings on this subject is fairly minor, making it an unattractive area for either privately sponsored research at public institutions or research conducted privately. In an excellent summary of soil and water conservation research history, Browning (1977) points out that 1862, 1887, and 1928 are landmark years in the history of publicly supported agricultural research in the United States. In 1862, Congress passed legislation that created the U.S. Department of Agriculture and also passed the Morrill Act which established our land-grant university system. The state Agricultural Experiment Stations were created by the Hatch Act of 1887 and 1928 McSweeney-McNary Act authorized forestry research. The USDA research agencies, the state Agricultural Experiment Stations, and the land-grant colleges, universities, and schools of forestry resulting from these acts now conduct about 95% of the nation's publicly supported agricultural research. This system also accounts for a high percentage of the erosion and sediment control research. The fact that a close relationship exists between these research agencies provides a unique opportunity to minimize the duplication of effort and maximize the coordination and dissemination of results to users.

The need for erosion control practices to maintain soil productivity was recognized even in the early years of this country by George Washington, Thomas Jefferson, and other pioneer agriculturalists. However, this need received very little public attention or support in that era. Shortly after the beginning of the century, Theordore Roosevelt's administration became the first to take a general interest in conservation, primarily the preservation of forests and irrigation of arid lands. The depression, and the dust bowl in the 1930's were a major factor in the establishment of major long range programs for soil and water conservation and in watershed development.

While government action was attempting to deal with some of the very evident problems of erosion and sedimentation, the scientific study of erosion has begun on a much less visible basis. Mitchell and Bubenzer (1980) point out that the scientific study of erosion effects began late in the 19th century

(Hudson.1971). They also state that the first quantitative experiments in America were begun by the Forest Service in 1915. Browning (1977) indicates that the first comprehensive effort to quantify the effect of length of slope and type of vegetation began with the establishment of the "erosion plots" in 1914 by M.F. Miller at the University of Missouri. Most of the early work gave results that were qualitative in nature, although a basic understanding of most of the factors effecting erosion was developed during the 1920s and 1930s.

In 1930, Congress appropriated funds for soil erosion and water conservation research, resulting in ten soil erosion experimental farms being established at different geographic locations throughout the country which represented a wide range of soils and climatic conditions. Other locations were also gradually established. By use of a standard experimental design in locations, date resulted that made it possible to evaluate the various factors which affect erosion under a wide range of conditions and also made it possible to extrapolate the research results to other locations where information was not available. Browning (1977) pointed out that an important beneficial spin-off of this early research effort was the opportunity provided the public at field days and other events to personally observe the effects of the various factors affecting soil and water conservation.

As the importance of raindrop impact, slope length and steepness, soil characteristics and cropping practices began to be realized, various scientists developed equations for soil erosion prediction. Much erosion and sedimentation research involves the use of small plots and small watersheds. Early researchers realized that there was a need to effectively relate the plot data to larger scale field conditions. Many of the erosion prediction efforts attempted to define field scale erosion, but the first to gain widespread adoption and to incorporate the large volume of data from the many soil erosion experimental farms was the universal soil loss equation (USLE). Browning (1977) points out that the widespread acceptance in use of this equation probably has done more than any other single effort to improve the quality of our conservation and land use programs. He also notes a growing concern that the USLE is sometimes used to extrapolate beyond the available data base. This data base is being continually extended, as will be noted in the discussion of current research activity, but the widespread current use of the USLE, especially in some mathematical models being developed, still has the data base limitation.

The use and limitations of the USLE will be discussed by other speakers on this program and will not be discussed in detail in this paper.

Current Research - Programs

The public concern for environmental quality which dramatically emerged in the 1970s gave significant new importance to erosion and sedimentation research. It became very evident that the concern was not only in maintaining the productivity of our agricultural lands but also that

excessive erosion was detrimental to air and water quality. In fact, it became evident that the primary incentive during this period for allocating public resources was the concern for environmental quality rather than concerns for maintaining productivity. Fortunately, there is essentially no conflict between the environmental quality objective and the maintenance of productivity objective, so that both have tended to lend strength and direction to the erosion and sediment control research effort. Since the USLE is and will continue to be a major tool in research, planning, and management efforts, there is still a significant amount of research effort devoted to defining the limitations and improving the quality of the prediction factors included in the equation. These efforts involve both the improving the accuracy of the factors for given local conditions as well as developing factor values for many new geographic locations under varying conditions.

While it would be prohibitive to attempt to describe the total erosion and sedimentation research currently underway, a summary of some of the broad topics being studied may be useful. Although I have grouped the topics by somewhat general objectives, there is interaction between each of these areas and they are not actually compartmentalized. Examples of current research areas include:

1. Improved prediction or estimation of soil losses from erosion.
   - Improving USLE factors
   - Evaluating USLE factors for additional conditions
   - Developing physical models

2. Improved prediction or estimation of sediment yields from watershed.
   - Identifying and evaluating source and deposition areas more accurately
   - Developing prediction models

3. Relation of erosion and sedimentation to water quality.
   - Identification of sediment borne pollutants and evaluation of their affect on water quality
   - Development of prediction models

4. Erosion control methodology.
   - Evaluating tillage, crop rotation, structural methods, land use change, and other erosion control methodologies and developing the management tools to make them successful for varying conditions
   - Development of models to assist in selection of methodology based objectives relating to water quality, reservoir capacity, maintaining productivity, least cost control, or others

5. Modeling - each of the earlier areas contained model development as a subsection. A myriad of models have been developed in recent years and are continually being refined. These include economic models, productivity models, models to target critical areas for control, management and planning models. When used within the limitations of the

data base and properly verified, the models can serve as very useful tools in planning erosion control methodology that will achieve objectives effectively with a minimum of resource input.

The major portion of this research is being done by engineers and scientists with Agricultural experiment Stations associated with the land-grant universities and by engineers and scientists with the USDA Agricultural Research Service (ARS). Many of the ARS research personnel are located at universities and collaborate on a continual basis with the university researchers. A much smaller research effort is conducted by scientists associated with other private and public institutions, federal and state agencies, private consultants, and industry.

The Agricultural Experiment Station organization also has a program of regional research projects, whereby a number of states cooperate in attacking a specific problem. This arrangement not only minimizes the duplication of effort, but allows timely exchange of results, advice and assistance between scientists from different states.
Regional effort also helps insure that research is being directed to priority areas, since all the cooperating states have to agree that the research problem is of significant priority to commit staff and resources to solving it. ARS and other agencies may also participate in these projects and frequently do. There are several regional projects dealing with the general area of erosion and sedimentation research in the North Central region and in other regions of the country.

A 1982 report (Larson, et al., eds. 1981) pointed out that federal support for soil and water resource research has remained nearly constant since 1966. Much of the emphasis during that period was on production-oriented research and has resulted in the obvious successes of abundance. Much of this abundance was at the expense of the soil and water resource, however, and since research support in this area has not nearly kept pace with research needs, it is probably realistic to say that the current research support is woefully inadequate, given the actual research needs. With very little profit motive involved, private support continues to be very minimal so the majority of this effort is publicly funded. While reallocation within the current structure is sometimes suggested as a means of additional funding for erosion and sedimentation research, the relative decline of public support for agricultural research and the important of many other programs makes this an alternative with essentially no chance for significant impact.

There is certainly progress being made in erosion and sedimentation research. Through demonstration and education programs as well as the development of tillage methods, chemicals, and other production inputs which allow production to be maintained with acceptable levels of erosion, progress is being made in the field also. We are far from having the answers to all of the problems, however, and the current research efforts to provide a solid foundation of facts for future efforts is inadequate by any measure.

Research Needs - Future

There are continuing efforts by various groups to identify priority research needs in erosion and sedimentation. This type of planning is desirable in order to keep research efforts directed in those areas which are high priority by consensus. With the limited research funding available, it is also desirable to direct funds to highest priority areas. Erosion and sedimentation research is by nature often long term research and often cannot be accurately simulated in laboratory conditions. When studying natural processes, it often takes many years of field data to provide a valid sample. To further complicate the situation, production practices often change so rapidly that the field conditions under study are obsolete and new ones are taking their place even before the results of the current research are complete and conclusions drawn. Thus some of the identified future research needs may also have been the object of past and current studies.

Research priorities may differ depending upon the geographical scale being addressed. Localized needs may differ from those identified as priority needs on state scale or on national scale. On a national scale, identified needs are often very broad, while on a local scale needs can be described much more specifically.

As an example of a recent effort, an interdisciplinary task force with several sponsoring government agencies and professional societies prepared a document listing national research priorities (Larson, et al., eds., 1981). The needs identified for agricultural land in humid regions are appropriate for Illinois and are listed as follows:

1. Conservation tillage technologies to sustain soil productivity.

2. Soil productivity and water quality - methods to analyze impacts of agricultural management systems.
3. Water management practices for improved soil and water conservation.

4. Land reclamation technologies for erosion - depleted soils.

5. Soil and water - conserving technology for land use conversion.

The list contains both short and long term needs. Long term needs must still address the basic causes and effects of erosion, as well as the principals of control. Short term research needs tend to be somewhat more applied, adapting results from more basic studies of a wide variety of situations.

The Illinois Water Quality Management Plan identified a number of research needs in the state. These needs were presented as part of an overall education and research program proposed by the University of Illinois in 1980 and included as part of the University budget request. This continues to be requested, but has yet to be funded. Current efforts are addressing some of the needs in a limited way. In fact, this is a special research priority

area within the Illinois Agricultural Experiment Station and is allocated extra funding, but even so, progress is severely limited by a severe lack of personnel and support. For this reason, needs identified by the WQMP are still very much with us. Areas included in the proposed research program include:

1. Evaluate the long-term affects of reduced tillage systems on diseases, insects, pests and soil losses. Some long-term studies have been redirected and some new studies have been initiated in this area, but they need to be expanded and refined.

2. Use existing economic and production models to determine the economic impact of possible higher costs of fertilizers and pest-control chemical.

3. Identify better means of estimating the effect of erosion on long term crop yield on various soil groups at varying fertility levels. The availability of relatively inexpensive fertilizers has made it possible for farm operators to mask the long term affects of top soil loss while maintaining yields. With increasing costs of fertilizers, however, the value of conserving surface soil may improve substantially.

4. Develop technology to reclaim B horizons (subsoils) for improved crop production. If worldwide food needs continue to increase, the productivity of the eroded soils may need to be improved to meet these demands. There is a need to investigate the possibilities of renovating eroded soils, those with either favorable and those unfavorable subsoils, for increased production. Current mineland reclamation studies may help answer some of these questions.

5. Develop methods of stabilizing or controlling erosion on sloping surface mined soils. Determine what methods work best for different materials and slope combinations, including establishing ground cover and mechanical methods.

6. Develop methods of stabilizing or controlling erosion during fall, winter and early spring on sloping soils after soybean harvest. Many soybean fields in Illinois that are not planted to wheat or some cover crop in the fall are subjected to serious erosion when left bare over the winter, especially if fall tilled.

7. Examine the incentive systems and strategies for speeding the adoption of technology needed to conserve our soil resources. Economic incentives that are to achieve soil conservation goals have not been very attractive. Incentives may increase with changing economic conditions, but appeals to other motives may be needed. A new conservation ethic may need to be developed.

8. Evaluate the effectiveness of applying soil conservation practices in improving water quality. Standard soil conservation practices were

developed to keep soil in place. Their effectiveness in reducing the sediment, phosphates, nitrates, pesticides, and other materials that reach streams needs evaluated. Each practice, including no till farming, terraces, etc., needs evaluation for meeting water quality standards.

9. Evaluate the impact of wind erosion on water quality and air quality standards. Wind erosion is seldom a problem in terms of its impact on the Illinois soil productivity, but plant nutrients, pesticides and particulate matter carried may be a serious water quality or air quality problem.

Priority establishment must be a continual process of evaluation and reevaluation. Priority evaluation for research must be able to identify emerging problems, minimize the likelihood of overlooking important needs, and prevent the waste of limited resources on low priority objectives. Those involved in research planning should also be concerned with maximizing the efficient utilization of scientists, facilities, and equipment and avoid unnecessary duplication of effort. Finally, the system must continue to improve the efficiency of getting research results into the hands of users. Effective communication must exist between researchers and the traditional educational arm, the Cooperative Extension Service as well as other organizations involved in planning implementation and communication, such as soil and water conservation districts, the Soil Conservation Service, and state agencies such as Department of Agriculture, Environmental Protection Agency and others. Not only is communication between groups necessary to get research information to the hands of users, it is also necessary to maintain the type of feedback from users to researchers that is necessary to assess the effectiveness, success and emerging problems that dictate new research needs.

In summary, past research has provided a foundation of facts leading to the technology of today. We can't assume that today's knowledge is adequate base for future needs, because we've all seen what happens when unforeseen, drastic changes in agricultural production practices occur. We need to continue adding research facts to the foundation to be able to develop successful technology for the future.

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PROSPERITY OR CATASTROPHE AS DETERMINED BY SOIL DEPTH AND DEGRADATION

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It has often been stated that man's existence depends on the thin layer that covers the earth — topsoil. It is true that topsoil is generally more productive than the soil materials found below it because the topsoil contains more organic matter, plant nutrients, has better water holding capacity and is easier to work. The process of soil erosion tends to degrade soil productivity.

We have many examples where soil degradation has continued until it became uneconomical to continue farming land. This land has generally been rolling to steep and has reverted back to native vegetation perhaps several times.

There are at least four challenges facing Illinois relating to soil degradation. The first is how to halt degradation. We have the knowledge to generally stop it; but we still have the problem, perhaps due to attitude changes, economic conditions, and lack of education.

The second challenge is to find ways of reclaiming degraded land and make it productive and useful to society. These two challenges are beyond the scope of this paper to discuss adequately.

The third challenge is to quantify the amount of past soil degradation and to project future soil degradation, if existing trends continue. It is this challenge that this paper will explore in more detail.

The fourth challenge is to determine the economic and environmental costs of soil degradation to a landowner, farmer, a watershed, community, region, state, or the nation. This paper will suggest a few avenues to explore, but those avenues are dependent on first quantifying past and future soil degradation.

Soil erosion causes two types of damages: on-site damages to soil productivity and crops; and off-site damages in the form of water pollution and the sedimentation of lakes, drainage ditches, road ditches, etc. The degree of damage depends to a large extent upon the nature of the soil and its position on the landscape.

Soil is a naturally organized body of layers with different physical and chemical properties. The soil profile offers a method of assessing the impact of soil erosion. The letters A, B, and C are used to designate soil horizons. The A horizon is the upper or surface layer and contains the

largest concentration of organic matter and plant nutrients; the B horizon, or subsoil, consists of weathered materials and higher accumulations of iron and aluminum oxides and clays. The C horizon is unconsolidated materials underlying the A and B horizons and has been little affected by the weathering process.

The A horizon plays the most important role in crop production by providing air, water, and plant nutrients. Plant roots and plant nutrients are concentrated in this layer, which may be only an inch or two think to 18 inches or more. In a cultivated soil, the A horizon may have been decreased in thickness or totally removed by soil erosion. When tilled, the A and B horizons may have become mixed. Removal of the A horizon by erosion can result in major changes in the surface soil characteristics. The water-holding capacity can be reduced; the clay content of the surface soil can be increased, making the soil more difficult to work and the future rate of soil erosion can be increased.

The B horizon may be favorable or unfavorable for root development. Some B horizons have excessive clay accumulations (claypan soils), have high density and strength (fragipan soils), have low pH, have high salt accumulations (sodium soils), have cement-like qualities, or have high aluminum saturation. The water permeability is often controlled by the B horizon, which affects both crop growth and runoff.

Composition of the C horizon material may vary from loess material to glacial till, sand or gravel. In some cases, bedrock either outcrops or is found at very shallow depths.

Our discussion has been on specific soil profiles, however, soils differ by their position on the landscape. Some landscapes have little slope with no major outlets, and sediment accumulates in depressional areas. This type of landscape is illustrated with the Drummer-Flanagan series. The Catlin soil has steeper slopes and thus a greater potential for soil erosion. The Flanagan soil, meanwhile, has less slope and less potential for soil erosion. Sediment from Catlin and Flanagan soils will accumulate on the Drummer soil.

The Alford-Wellston series is found in southwestern Illinois near the Mississippi River. The depressions are quite deep and most of the eroded soil will be carried out of the cultivated area. Soil erosion tends to be severe on all the soils within the area due to slope steepness. These are the two extremes in types of landscapes found in Illinois — landscapes that range from level to steep.

Estimates of yield reductions from soils with different degrees of soil erosion and slope steepness are made in University of Illinois Circular 1156, Table 1. The soils are first divided into those with favorable and unfavorable subsoils and for high and basic management levels. Crop yields are also affected by the slope. I have developed a chart showing the

expected yield reduction from soil erosion for a Clarence silt loam soil with a 4 percent slope. The Clarence soil C horizon consist of glacial till, which greatly restricts root development. The productivity index set for the uneroded Clarence soil is 100 bushels of corn per acre (Figure 1).

The reduction in crop yield will be about half as much on soils with favorable subsoil, for it is easier to overcome yield reductions using fertilizers and management on soils with a favorable subsoil.

The methods of estimating yield reduction, as illustrated in Circular 1156, essentially provides three basic points on the yield curve. It is difficult to tell just where you are on the curve except where erosion has not occurred.

Steve Probst has been working on a system to help pinpoint just where you may be on the soil erosion curve. Steve will explain his system.

As with all studies, some basic data and information were needed. The first data needed were a sampling of soil profiles in a given area at a given point in time. With 60 modern soil surveys in Illinois, each of which was completed in a relatively short time span, a large existing data base was available. But, there are two basic features of soil surveys that cause minor problems for a soil degradation study. First, minor acreages of different soils are often combined during correlation or actual mapping. For instance, let us assume that a soil scientist finds a small area of Fayette silt loam, 10 to 15 percent slopes, moderately eroded; but it has been determined this soil only occurs on a minor acreage in the soil survey area. The final soil map would probably show this area combined as Fayette silt loam, 10 to 15 percent slopes, severely eroded, if that mapping unit were on the soil survey legend. The second basic feature is that soil descriptions of each boring are not completed. Some sample detailed descriptions are completed in the soil survey area, but day-to-day mapping is dependent on the field observations, simple field tests, and judgement of the soil scientist.

Over the initial study areas (20,000 to 30,000 acres) these features did impact, but for the scale of the study, the error was estimated to be plus or minus 2 percent.

The second soils data base was <u>Soil Survey Laboratory Data and Descriptions for Some Soils of Illinois</u>, Soil Survey Investigations Report No. 19, SCS, April, 1968. This report contains soil descriptions and laboratory data for many of the eroded soils.

Finally, random samples of soil mapping are available for several watersheds from the Natural Resources Inventory.

Our first attempts at soil degradation were based on the premise that if we could determine the past erosion rates from day one of cultivation, we could then add the yearly average soil losses to get the total tons lost and thus

the amount of soil degradation that had occurred. We tried looking at past agricultural statistics to determine cropping patterns and thus 'C values' for the Universal Soil Loss Equation. The task proved impossible for three reasons. One, the data did not go back far enough. Two, there were only vague records of when the areas were initially cultivated. Three, the data were too general for use in specific areas.

We then decided to evaluate which factors of the USLE would have been relatively constant over time. Those factors are the rainfall factor (R), the soil erodibility factor (K), and the slope - length factor (LS). That left the cultural practices factor (C) and conservation practice factor (P) that might have varied over time.

Using available watershed data where R would be constant, regression analyses were run between the USLE factors (except R) and the current soil loss rate. Statistical T tests were then executed.

The r^2 value for a combination of K and LS was 0.96. The T rejection was 1.6 and the calculated T was 50.9. Only the LS factor regression exceeded the 1.6 also with a calculated 42.7. No other regression exceeded the value of 1.6.

Karr (1980) in Illinois also found in similar studies that 'KLS' could be used for predicting erosion rates. In other words, the 'KLS' factor combination was the key in determining the variability in soil losses between soil mapping units within a watershed. It is then reasonable to assume that past erosion would also have been relative to the 'KLS' factors. It must be noted that the watersheds studied were predominantly cropland. Additional study is needed on other land uses.

The next step was to analyze the distribution of soil mapping units by erosion phase relative to their 'KLS' values. Figure 2 shows a sample distribution for Spring Lake Watershed near Macomb, Illinois. The point at which a soil mapping unit has the same probability of being erosion phase one or erosion phase two was then calculated. That point or 'KLS' is 0.1423.

Next, using the data available in the Soil Survey Laboratory Data and Soil Descriptions for Some Soils of Illinois, typical profiles were used to establish the surface organic matter percentages for the soils at the breaks between erosion phases. A degradation model, 'DGRD' ILCP061382, 'eroded' each of the soils to determine the inches of surface that would have been lost at each of the erosion phase breaks. Using the soil bulk densities, the total tons lost was also calculated. Then using the 'KLS' values for each mapping unit, the tons lost as of the date of the soil survey were also calculated (Figure 3).

With this procedure then, using the soil survey as a point in time, the past amount of erosion could be estimated. Procedure: Current average annual erosion rates can be determined by using the Universal Soil Loss Equation.

Therefore, to predict future soil degradation, one simply multiples the current erosion rate times the number of years and adds that figure to the tons of past erosion. For example, a soil in the past has lost 650 tons of surface soil. This soil is currently at erosion phase one, but is eroding at the rate of 15 tons per acre per year. In 10 years, it will have lost 800 tons of surface soil.

Bost (1981) made perhaps the best attempt to date to tie together soil degradation and its impacts. This analysis looked at 16 Illinois soils and at the impacts over time on net returns due to erosion. We currently have productivity estimated based on Soil Productivity in Illinois, University of Illinois Circular 1156, which vary by soil and erosion phase. Estimates can then be made of the impact on yield as a soil degrades. However, additional studies are needed.

First, continuing work is needed on yield versus erosion. The costs of maintaining production on eroding soils also must be studied. We need to know that if even with additional compensating inputs, are yields as consistent on eroding soils?

Second, we need the ability to measure for the farmer the impacts of erosion control measures on his net income, on the economic welfare of his community, and on his and his community's environment.

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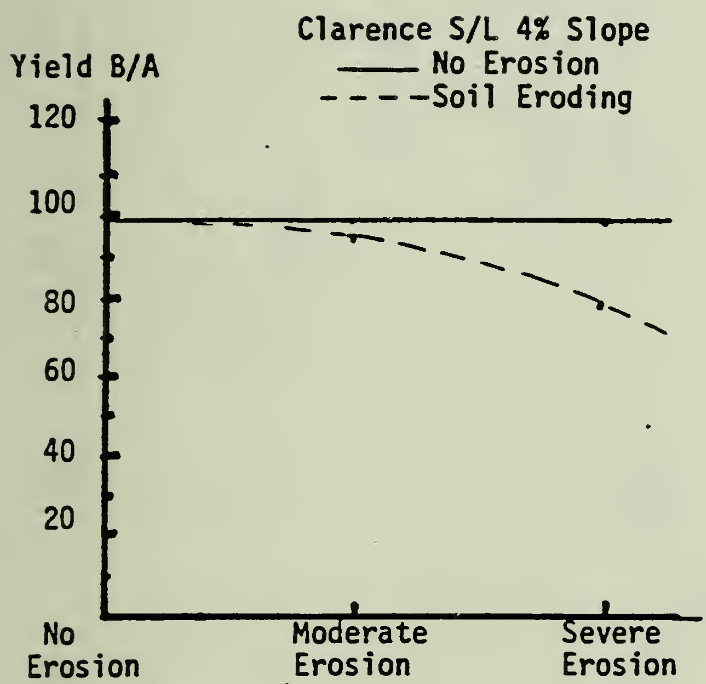
FIGURE 1



Clarence S/L 4% Slope
No Erosion
Soil Eroding
Yield B/A
120
100
80
60
40
20
No Erosion
Moderate Erosion
Severe Erosion

FIGURE 2

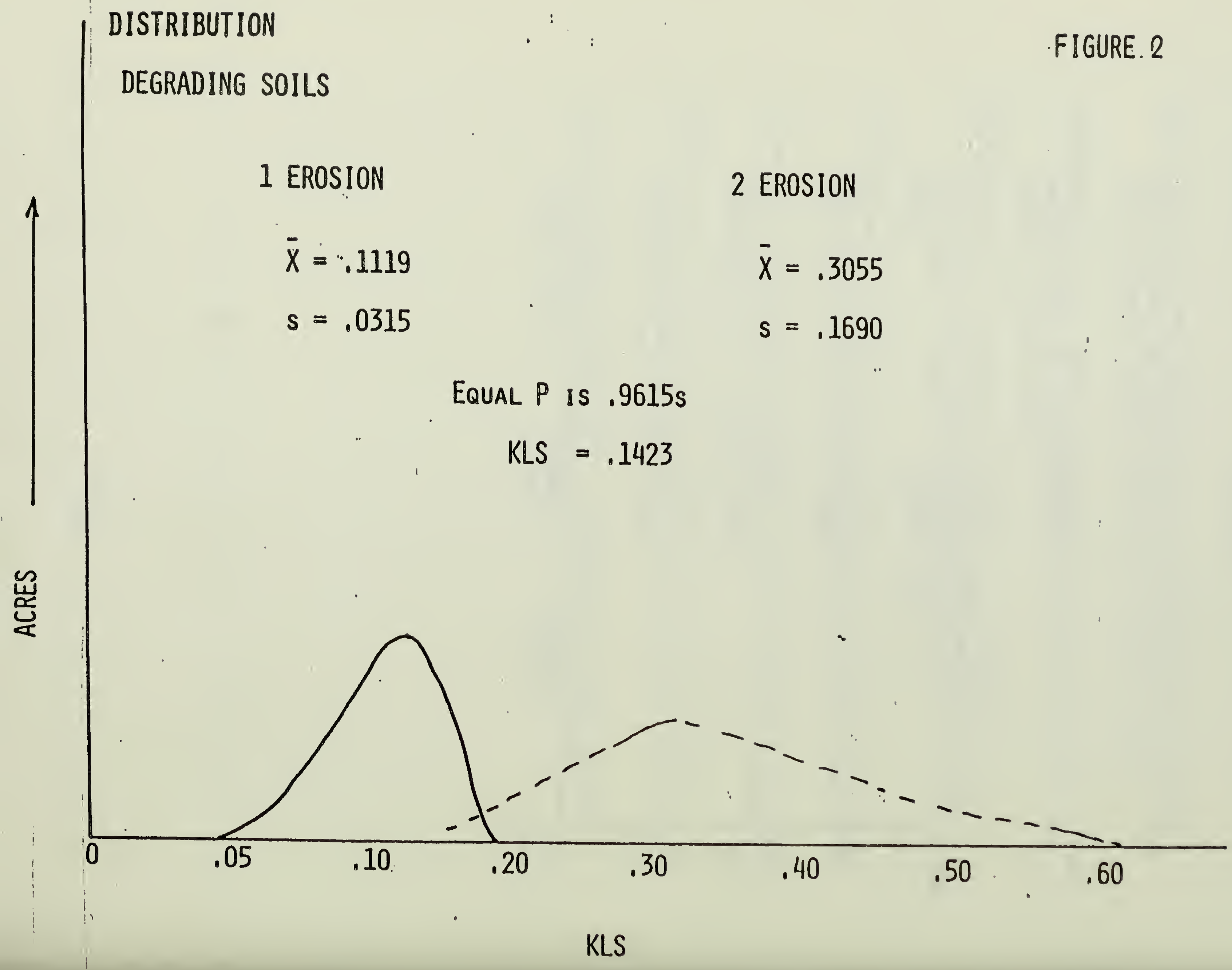
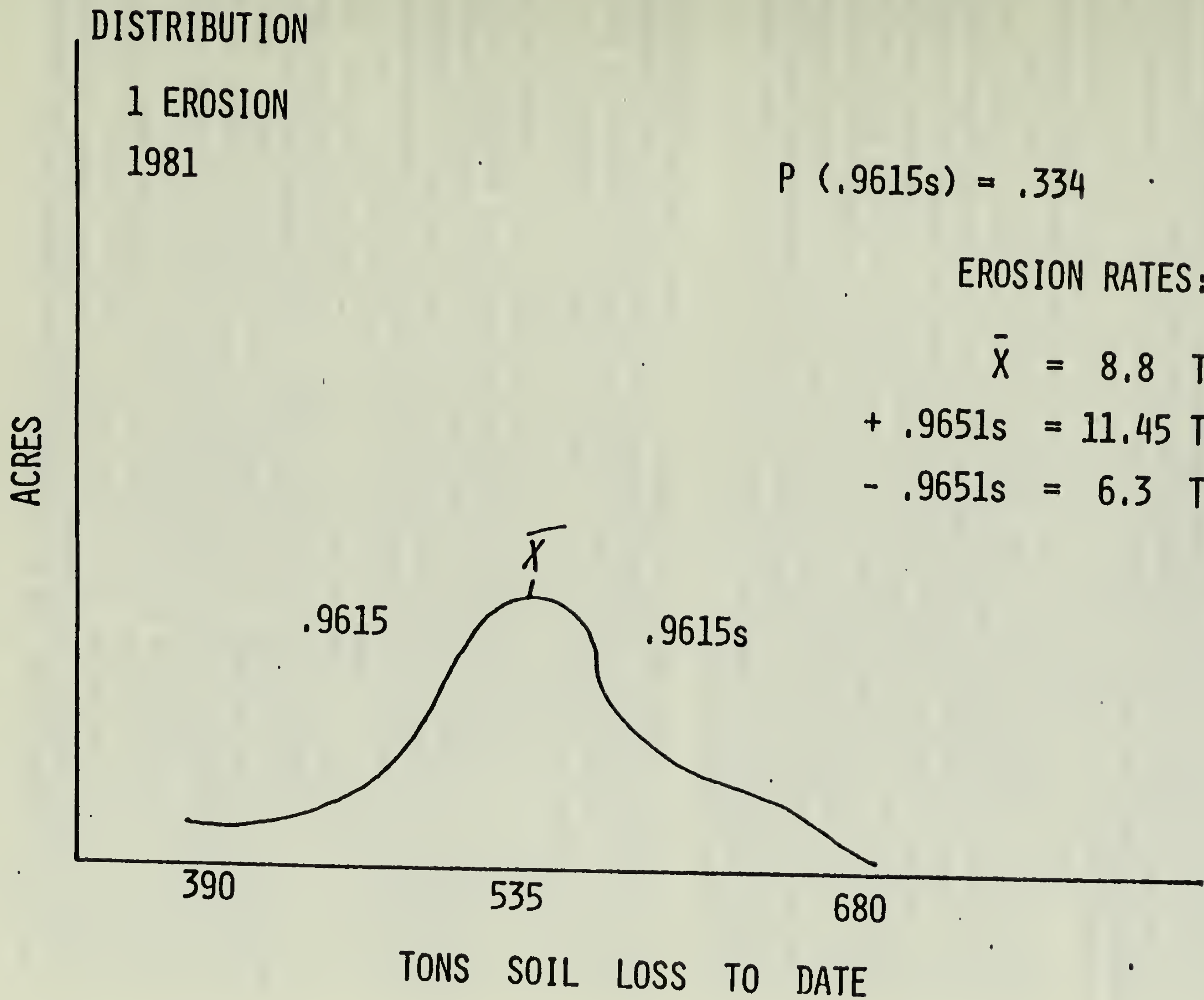

DISTRIBUTION
DEGRADING SOILS
1 EROSION
$\bar{X}$ = .1119
s = .0315
2 EROSION
$\bar{X}$ = .3055
s = .1690
EQUAL P IS .9615s
KLS = .1423
ACRES
0
.05
.10
.20
.30
.40
.50
.60
KLS

FIGURE 3



P (.9615s) = .334

EROSION RATES:

$\bar{X}$ = 8.8 T/Ac/YR

+ .9651s = 11.45 T/Ac/YR

- .9651s = 6.3 T/Ac/YR

THE SOCIOECONOMIC ASPECTS OF THE HIGHLAND SILVER LAKE RURAL CLEAN WATER PROJECT

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The Highland Silver Lake Rural Clean Water Project (RCWP) is one of five projects which have been allocated funds for a Comprehensive Monitoring and Evaluation (CM&E). Part of this CM&E is to consist of a socioeconomic evaluation which should analyze the costs and benefits of the RCWP implementation.

While the Economic Research Service of the United States Department of Agriculture (ERS-USDA) bears the ultimate responsibility for this socioeconomic analysis, they have contracted with the Department of Agricultural Economics of the University of Illinois to conduct part of the work, namely, that of examining the onfarm/onsite impacts of the RCWP implementation. To complete this portion of the socioeconomic analysis, two phases of work have been planned. In the first, which is reported in this paper, the economic and physical impacts of implementing RCWP approved Best Management Practices (BMP's) will be examined at the individual farm level. The next major phase of research, which is now underway and scheduled for partial completion by October of next year, will estimate similar impacts on the entire watershed area.

Highland Silver Lake is an impoundment of the East Fork of Silver Creek in the northeast corner of Madison County, and western portion of Bond County, Illinois. The watershed includes approximately 30,000 acres of land. Its location relative to the State and Nation is shown in Figure 1.

The impacts of the RCWP on participating farmers should ideally be analyzed by making a comparison of the status of farmers after the RCWP has been implemented to their status at the same point in time had RCWP not been implemented. This would be the ideal "with" and "without" comparison. Since RCWP has, in fact, been implemented in the Highland Silver Lake Watershed, it is not possible to directly observe a "without" condition. Two alternatives to a true "without" observation are to use the "before" project conditions as a base for comparison or to somehow project what would have happened in the watershed if RCWP had not been implemented. The former option has the advantage of having been observable at a point in time, but it does not account for the possibility that farmers are constantly adjusting their operations in response to past and anticipated future changes in prices, resource availabilities and government policies, programs and regulations. The second option allows the analyst to make reasonable assumptions about farmers' decision making objectives and to create or build a behavioral model which would estimate the farmers' "without" project future situations. This approach obviously has the disadvantage of not being able to completely

represent farmers' objectives and not being able to predict future changes in the decision making environment.

The socioeconomic analysis relies most heavily on the second option outlined above. For the "without" RCWP situation multiperiod linear programming (LP) models were used which assume that the operators of the representative or typical farms are profit maximizers who evaluate the results of their operations over a 50 year planning horizon. This assumes that they recognize the long run productivity impact of alternative management practices, i.e., that some practices cause more erosion than others and therefore will adversely affect yields, but that they also discount future income more heavily than current income. Therefore, the future income losses from heavy erosion causing practices may or may not be changed enough to induce farmers to adopt conservation depending on the relative profitability of these practices in both the short and long run.

The "without" RCWP future scenario is not altogether unconstrained. Illinois' Section 208 planning process for the Federal Water Quality Act Amendment has resulted in a series of voluntary soil loss limits which become progressively more stringent through time (Illinois Department of Agriculture). These soil loss constraints have been incorporated into the "without" future scenarios of the LP model. The "with" RCWP scenarios also incorporate these soil loss limits but in addition, they incorporate the cost share payments available for approved Best Management Practices (BMP's). Thus the "with" RCWP scenarios offer the farmers the option of whether or not they will participate in RCWP depending on whether it is profitable to do so.

Five representative or typical farms were constructed for this analysis. The locations of the farms within the watershed are shown in Figure 2. The representative farms were constructed in the sense that they do not correspond to actual farms. The boundaries of the representative farms were chosen so as to include areas being monitored by field sites in the water quality portion of the evaluation. Some of the more important characteristics of these representative farms are given in Table 1. Included in these characteristics are the "before" RCWP farming activities. Although "before" conditions have the drawbacks noted earlier for evaluating costs and benefits, it may nevertheless be instructive to make some before and after comparisons.

The results of the socioeconomic analysis will be initiated by first presenting the physical outcomes, including how farm management practices are affected by RCWP implementation, to what extent gross erosion will be changed, and the impact on soil productivity through time. Subsequent sections will examine economic effects and implications of RCWP.

<u>Farm Enterprise Changes From RCWP</u>

The combinations of management practices chosen by the LP model for each farm, during each 10 year period, under both the "with" and "without" RCWP

policy options are presented in Table 2. This table also shows the average annual soil loss from each representative farm which was modeled. For most of the farms, the profit maximizing solution also satisfied Illinois' limits on erosion, therefore the additional constraint that solutions meet these limits had no effect. Only on farm two were some acreages forced into a conservation practice which would not otherwise have been selected. The "without" RCWP profit maximizing solutions included mostly permanent hayland or row crops grown under no till. These combinations of crops resulted in estimated erosion levels which are far below T-values (tolerance limits on erosion) and far below the erosion levels for the "before" RCWP crop selection. The T-values for the aggregated soil groups on the representative farms ranged from 2.4 to 5.0 tons/ac./yr. The average annual erosion levels, for the "without" RCWP model solutions resulted in estimated average annual erosion levels of from 0.90 to 1.70 tons/ac./yr. on a whole farm basis. These results would seem to indicate that if farmers would move to profit maximizing cropping enterprises, they would, at the same time, substantially reduce erosion levels. Presumably, reductions in erosion would also result in reductions in water pollution, but affirmation of that presumption must await the results of further water quality monitoring and physical/biological simulation analysis. Comparing Tables 1 and 2, the reader can easily see that the profit maximizing farm organizations involve a greater use of no till and reduced tillage systems and greater areas devoted to rotation pasture or permanent alfalfa pastureland or hayland. The crop budget analyses performed for the watershed area showed that these systems were more profitable in the short run, and since they also save topsoil, would continue to be more profitable in the long run as well.

The LP analysis showed that the availability of RCWP cost sharing funds would induce profit maximizing farmers to make only minor adjustments in farm enterprises when compared to the "without" RCWP choices. These changes consisted mainly of shifts to no till from reduced tillage and away from permanent pasture to rotations including at least some row crops. These changes tended to be kept in place only during the first, ten year period, during which cost share funds were available. The farm plans tended to revert back to the "without" RCWP plans when the cost share funds expired at the end of the first, ten year period.

Soil loss estimates for the "with" RCWP situation were actually somewhat higher than for the "without" situation on all the representative farms except number two. The reason that this occurred, which will be elaborated on later, is that less profitable systems, which are also slightly more erosive, now become more profitable with the addition of the cost share payments. It should be emphasized, however, that the difference in soil loss is relatively quite small and that the "before" RCWP or present farm enterprises result in considerably higher soil losses (see Table 1).

Productivity Changes From RCWP

The LP models constructed for the representative farms were designed to incorporate the productivity impacts of soil erosion on crop yields. A simulation model was developed at the University of Illinois which simulates, over a long run planning horizon, the physical and economic impacts of various crop management system. This model, know by the acronym SOILEC (SOIL conservation EConomics) (Eleveld, Johnson and Dumsday, 1983), was used to estimate crop yield levels for the crop rotation - tillage practice - mechanical erosion control practice combinations which constitute the management alternatives allowed in the representative farm LP models. The initial estimates of crop yields for each major soil group on the representative farms is given in Table 3. The initial yields reported in Table 3 are weighted averages of the yield indices for the component soil types in each group as available from Illinois Cooperative Extension Service Circular 1156, entitled "Soil Productivity in Illinois". Initial yields ranged from a high of 153 to a low of 34 bu./ac. for corn. For soybeans, the yields ranged from a high of 50 to a low of 12 bu./ac.

Obviously the rate at which crop yields would decline through time depends not only on the characteristics of the soil but also on the cropping management system selected. Tables 4 through 6 show some examples of how corn yields would be affected by the various cropping management practices available in the LP model. Yields for the other crops would be reduced at a similar proportional rate, starting from the initial values given in Table 3.

Table 4 is for the soil group with highest average initial yields. All the soils in this group are in the 0 - 2 percent slope range and therefore the erosion rates for all management systems are relatively low and the losses in productivity are also quite small. These results were quite typical of soils with relatively flat slopes.

Table 5 is somewhat typical of soils which have greater slope and intermediate initial yield indices. The drop in corn yields ranges from 17.3 bu./ac. for a CS - NT system to only 7.2 bu./ac. for a CCSWMMMM - NT system over the 50 years that yields were simulated (see the footnote to Table 1 for the legend to this rotation - tillage notation). On this type of soil, fairly significant yield gains can be made by choosing a soil conserving system.

Table 6 is also fairly typical of many of the soil groups in the watershed. The soils in this table are quite steep (5 - 15 percent) and have very low initial yield indices. Despite the fact that erosion rates are high, yields do not decrease substantially because there is, in essence, no place for them to go. For practical purposes, it does not pay to raise row crops on these soils and LP model solutions typically put these areas into permanent hayland or pasture.

Impacts on Net Returns of RCWP Cost Sharing

Current legislation allows for cost share payments to farmers who reduce their tillage or convert cropland to permanent pasture. Cost share payments according to present laws, will only occur in the first period of the model since each period covers 10 years. The LP model for the HSL Watershed is run with and without these payments to see how cost sharing effects farm income and soil erosion.

As one would expect with transfer payments, the results show that total income (Table 7) and annual per acre income (Table 8) increase for the five representative farms when cost share payments are made to farmers. The net return increases ranged from approximately 1.4 to 5.1 percent at the zero discount rate. Farm three has the highest percent increase and farm four has the smallest.

In several instances, the cost share payment caused the optimization model to change activity selection from the "without" RCWP conditions, as could be seen in Table 2, thereby diluting the total dollar benefits of the transfer. When the activity chosen in the cost share results does not appear in the non cost share solution, the model is selecting a rotation - tillage combination that has a lower per acre net return without transfer payments. Therefore, in the modeling scenarios, some of the transfer payment is being used to compensate for an initially less profitable rotation - tillage system. This is as it should be if erosion and/or water pollution are being reduced, but for most of the representative farms, the opposite effect is seen. Since farmers are not changing from baseline practices, but rather changing from present or actual practices, the implication is that better conservation results might be obtained with lower transfer payments by inducing farmers to actually change to the baseline or "without" RCWP practices rather than the practices recommended in the cost share scenario. Let us examine the results for farm one as an example.

On soil group C, the non cost share model selected permanent hayland with a $62.27/ac. net return (before cost share payments are included). With the $157.50/ac. cost share payment for no till, the row crop activity became the most profitable for soil group C. However, $6.69 (62.96 - 56.27) of the cost share payment is lost due to the activity change. The farmer, in the modeling context, would have been better off, in net income terms, if he were paid the $157.50 to switch from actual practices to those optimal in the "without" RCWP scenario results.

Due to the activity changes outlined above when cost share payments are included in the model, total soil erosion and annual per acre soil erosion increased from the baseline conditions, for all farms except farm two, at all three discount rates. These results can been seen in Tables 9 and 10. Erosion increases from the baseline scenarios range from approximately one percent on farm five to almost 11 percent on farm four. The percentage increase in erosion on farms one (9%), three (9.4%), and four (10.8%) are

fairly high but, in all instances, the average annual erosion levels are far below the T-values for each farm. Farm two is the only representative farm where erosion levels decline with cost share payments.

The purpose of cost share payments, as allowed for in current legislation, is to induce farmers to switch to a less erosive rotation - tillage system, thereby encouraging soil conservation. However, as the results in Table 10 demonstrates, if farmers shifted from current practices to profit maximizing activities as indicated above in the baseline model, the soil would have been effectively conserved under non cost sharing conditions. In effect, in these scenarios, and with these assumptions, there would be no need for cost sharing payments to be made to a farm operator other than to have increased his net income. If the LP models are correctly specified, it would seem to indicate that quality education of farmers about the income potential of the baseline solutions might be a more effective conservation strategy or to target transfer payments towards these practices. Actually, a farmer cropping as in the no cost sharing circumstances would not have been eligible to receive cost share payments since, in general, the cropland is adequately conserved with the non cost sharing activities. Later in this section comparisons will be made with the current activities on these representative farms and the reader may see why, in a less theoretical setting, cost share payments may still be effective in achieving conservation objectives.

Cost share payments only affect the net income during the first period on each farm. These results can be seen in Table 11. On a per acre basis, the increase in income was \$146.91, \$132.86, \$107.82, \$72.69, and \$156.49 for farms one through five respectively in the first period. The change in rotations during the first period can be seen in Table 2. In general, the transfer payments encouraged the use of more no till cultivation. If highly erosive rotation - tillage were the initial or present set of activities with no cost share payments, this would be a desirable result to satisfy the objectives of conservation legislation.

In most instances, in the non cost sharing scenarios, the rotation - tillages selected in the early (first) ten year period are the same as those selected for all periods. In general, the short run considerations are analogous to those of the long run ion terms of profit maximization and soil conservation. In the cost sharing cases, the model often selected different activities in the first period than it did for the later periods. Therefore, results indicate that an operator would view the short run in a different context from the long run when cost share payments are only available for a short time horizon.

Terracing and contouring are two mechanical conservation practices included in the model as alternatives to reduce soil erosion. The results show that neither activity was selected on any farm in any period for any policy scenario. Terracing and contouring, as included in the model, are relatively more expensive methods for reducing soil losses from a field compared to switching to other rotation - tillage combinations. Also, with such low

baseline erosion levels, the large erosion reduction affected by mechanical conservation practices are usually not necessary to achieve conservation targets.

Current Management

Present management practices occurring on the representative farms differ considerably from the activities selected by any scenario in the optimization models including the baseline. Currently, the most common cropping system on these farms is a CSW/S rotation with non contoured conventional tillage. Other rotations are found to a lesser extent with some reduced tillage acreage. Table 1 summarized this information for each representative farm along with the average erosion that occurs under present land management conditions. In each farm, current management practices are resulting in erosion rates in excess of a weighted average T-value for all soil groups on the particular farm. For farm four, the erosion rate is considerable higher than the T-value. The results from the optimization model demonstrates that operators of these representative farms could reduce erosion levels significantly by changing from their current rotation - tillage practices to those suggested by the LP model while simultaneously increasing their farm income and preserving the long run productive capacity of the soil. Present farming activities demonstrate erosion levels that are detrimental to the long run quality of the farmland and operators may not be maximizing their long run income.

The results of the baseline or "without" RCWP run of the LP models do not reflect what the farmer is currently practicing but what he should or would practice if he were to maximize net income in the long run. There are several reasons why existing practices may differ from those chosen by the baseline model. First, farmers are not pure profit maximizers. They incorporate other objectives and preferences into their decision making process. One of these preferences may be an aversion to changing to any new practices and technologies (such as a livestock to utilize the hayland). Second, shifts to practices recommended in the baseline model may involve significant investments in new or different equipment. Credit availability and cash flow difficulties may present barriers to these changes. Third, representative farms chosen for analyses are hypothetical farms and as such do not represent actual complete economic units under the control of a single, actual decision maker. This problem could still have surfaced even if actual representative farms had been chosen since many operators in the watershed also farm acreage outside of the watershed. Fourth and finally, these results do no reflect the degree of riskiness perceived by operators for the alternative activities nor their risk attitudes. This is, or course, related to the first qualification but it is possible that farmers perceive conservation technologies as having more variable results even if the average or expected results are higher net incomes.

Critical Assumptions and Sensitivity Analysis

Many different assumptions were made at the outset of this investigation. It is important in any optimization analysis to determine how sensitive the results are to changes in the initial assumptions. If the activity selections are unaffected by rather large adjustments to the model's parameters then one can be fairly confident in the solution. If the results change with slight adjustments in the parameters, then the solutions are considered to be highly sensitive to the initial assumptions and results may be less conclusive than in the former case above.

The baseline budgets utilized to compute the annual per acre net return parameters for each activity were crucial to the final rotation - tillage selections. Prices, yields and inputs might all be subject to changes. In addition, inflation, technology, management, and market conditions could all have fluctuated and influenced the model's coefficients in the time horizon of this study. The potential number of combinations on which one could make sensitivity tests were too numerous to attempt all of them. After careful review of the results, it was decided to experiment with two specific sets of adjustment to the assumptions for sensitivity analyses.

While the hay price initially assumed may be reasonable for the present situation, its usefulness would be suspect if large acreages were to be converted to hayland as suggested by the model results. There is no well organized cash market for hay and livestock numbers in the area are limited. Therefore hayland expansion would either reduce local hay prices or farmers would need to truck the hay long distances to other markers and the associated transportation expense would have the same effect as a lower price. Therefore, for the first sensitivity analysis, the effects of reducing the price of hay by 10 percent were examined.

Another crucial assumption was that the three tillage systems would have equivalent crop yields for any given topsoil depth. Conflicting research data indicates that yields for a no till system could potentially be lower than those for conventional or reduced tillage. Therefore, in the second sensitivity study, the effects of reducing yields in the no till rotations by 5 percent from conventional and reduced tillage systems were examined.

The sensitivity analyses were performed on farm three to demonstrate the effects of these changes. The additional runs were done only for the 0 percent discount rate. Space and time limitations forced the exclusion of sensitivity analyses on the remaining representative farms and other discount rates. However, a cursory survey of the data indicated the results would have been similar to those of farm three.

Effects of Reduced Hay Prices

A 10 percent reduction in the price of alfalfa hay, from $58.00 to $52.20 per ton, affected the net returns for the CCSWAAAA and AAAAA rotations only.

Since the hay in the CSWM rotation was clover, and was considered to be used for grazing pasture only, it was felt that parameterizing this price would serve no useful purpose. With this hay price adjustment, the results show that net income declines and soil erosion increases for all scenarios. In addition, there is a significant increase in cropland devoted to no till cultivation and a large decline in permanent pasture. The top half of Tables 12 and 13 summarize these results.

Net returns, compared to the initial runs, decrease by 16.6 and 13.7 percent for each scenario (in order of their listing in Table 12) indicating that a drop in the price of alfalfa hay would have a significant impact on farm income. Reducing hay returns also had an impact on soil losses. For the non cost sharing situation, soil erosion more than doubles and increases by 38 percent for cost sharing. These rather large soil erosion increases can be traced to the shift in the rotation - tillage activities. When hay prices are reduced, rotations with alfalfa looked less attractive in terms of per acre net returns and the no till activities, in most instances, replace permanent pasture in the optimal solution (see Table 13, top half). The no till rotation - tillages are more erosive than permanent pasture and this resulted in higher soil losses. Therefore, reducing the price of hay showed that cost share payments could have an effect on reducing soil erosion by causing a shift from reduced to no till in the first period. In all instances, however, average farm erosion is still below the T-values.

In summation, the effects of reducing the price of alfalfa hay by 10 percent show that the initial results were highly sensitive to such a change. The hay price sensitivity analyses produced results more in line with other studies where there was more of a tradeoff between short term profitability and soil conservation.

Effects of reduced No Till Yields

A second sensitivity analysis was performed assuming, in addition to a reduced alfalfa hay price, that the yields on no till activities were 5 percent lower than those of conventional and reduced tillage. The level of the reduction was somewhat arbitrary; however, it seemed appropriate to see how sensitive the results were to slight yield reductions. Yield projections were difficult to forecast in a study such as this one and the decision to reduce no till yields was not meant to imply that such a tillage system would necessarily have resulted in lower per acre output. Research data implies, and farmers perceive, that no till yields are more variable than those of other tillage practices and more sensitive to environmental conditions. If erosion levels are high in conventional tillage systems, then in the long run, no till yields will probably be higher than those of conventional tillage. However in this watershed, erosion levels are relatively low so there is some probability that a reduced no till yield might be apparent in production activities.

The bottom half of Tables 12 and 13 show the results for a combined reduction in no till yields and alfalfa hay prices. Net returns decline for each scenario when compared to both the initial results and the first sensitivity analysis. In comparison to the initial net returns, farm income decreases from 17 to 23 percent. The annual per acre net returns declines from approximately \$42 - \$44/acre to \$32 - \$35/acre. These results indicate that a reduction in the yields on no till crops plus a reduction in the price of hay would have a noticeable impact on farm income. This sensitivity analysis also demonstrates erosion levels three to four times higher than the initial solutions.

These results showed that cost share payments affect a reduction in soil losses. This can be attributed to the selection of no till activities in period 1. The larger transfer payments for this tillage practice offset the reduced returns from lower yield expectation.

The net effects of assuming lower no till yields and lower hay prices are higher soil erosion and lower farm income than would have been obtained under the initial assumptions and under the first sensitivity analysis. Such results further indicate that the initial results are highly sensitive to changes in the initial assumptions. As in the first sensitivity analysis, these results are more in line with the initial expectation and demonstrate the effectiveness of the erosion limits instituted by the state in reducing soil erosion. However, without cost share payments such controls would have a negative impact on farm income.

A Note on the Effect of Size of Farm on Economic Impacts

Policy makers are often interested in whether government programs will have a different impact on large versus small farms. None of the results of this study would support a conclusion that this would be the case. Most of the differences in economic impact seem to be more related to the quality of the land endowment of a particular farm. While the difference in net income between "with" and "without" RCWP situations was the smallest for the smallest farm (see Table 8, farm four), this farm also had the highest net income on a per acre basis. On the remaining farms, no clear-cut relationship could be discerned which related to farm size.

A Brief Summary

Cost share payments would increase farm income but in four of the five representative farms, erosion losses would also increase from the baseline results. None of these results demonstrated the need for the RCWP if farmers in the watershed were assumed to be practicing profit maximization tillage - rotations and if the initial assumptions made in this study were correct. Erosion reductions would, however, be realized by moving away from actual or "before" RCWP activities, but better or more cost effective results might be obtained by better targeting of payments. To the extent that the actual conservation planning of participating farms is somewhat of "bargaining"

process, the relatively small differences between the "with" and "without" RCWP scenarios might not be as important as the large gains that can be obtained by getting farmers to abandon current or "before" RCWP practices.

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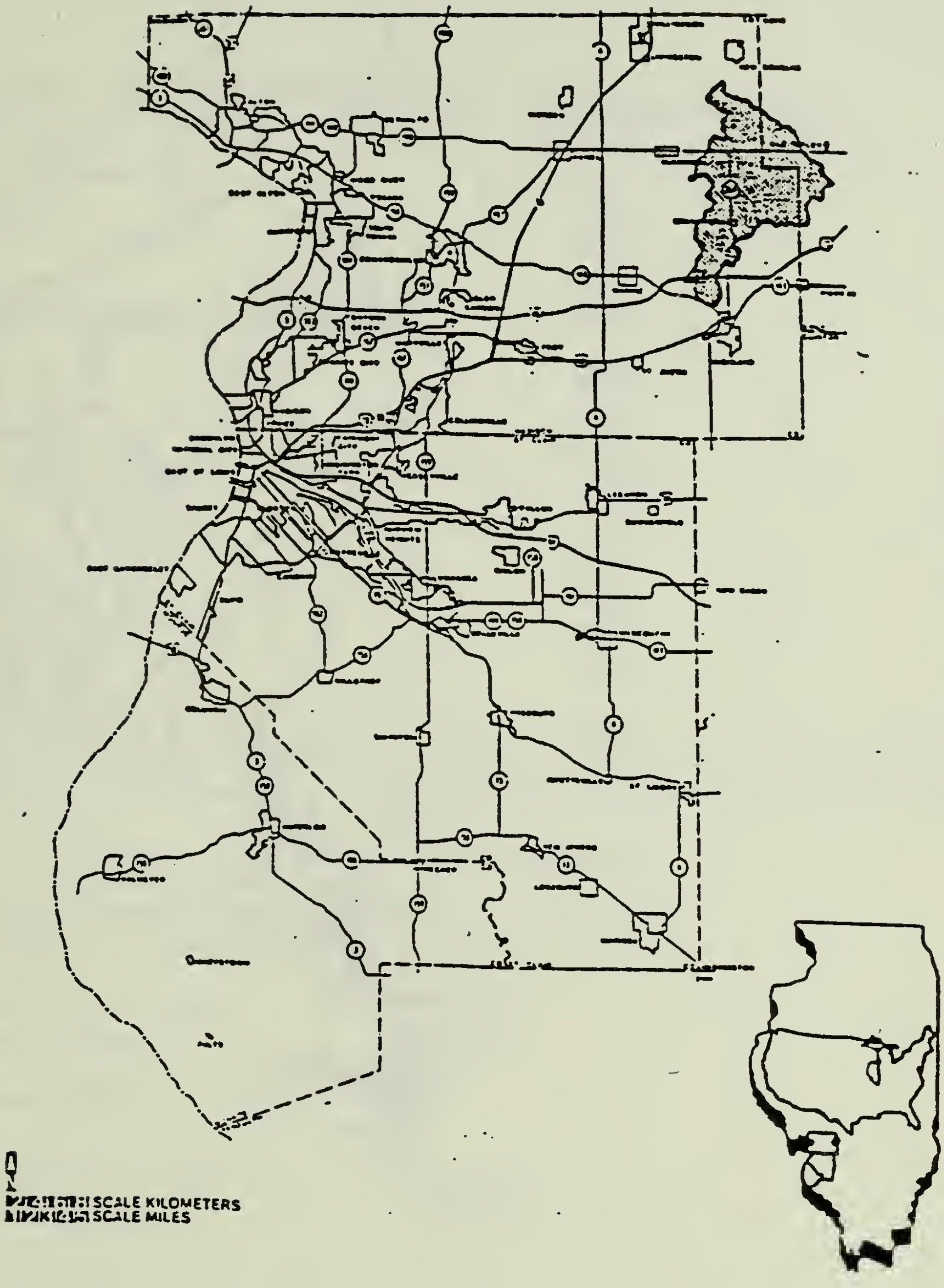

Figure 1: Regional Location of the Highland Silver Lake Watershed.

Figure 2 : The Highland Silver Lake Watershed with the Five Representative Farms Outlined (not drawn to scale).

Table 1. Crop Rotation and Tillage[a] Practices Currently Employed on Each Representative Farm in the Highland Silver Lake Watershed.

Farm	Farm Size (ac.)	Current Average Farm Erosion Levels (TAY)	Current Management		Portion of Farm in Activity	
			Rotation[b]	Tillage[c]	(ac.)	(%)
1	998	3.5	CSW/S	CT	778.4	78.0
			CSW/S	RT	111.8	11.2
			CSWM	CT	107.8	10.8
2	416	4.3	CSW/S	CT	416.0	100.0
3	290	4.0	CSW/S	RT	80.3	27.7
			CSWM	CT	67.6	23.3
			CCSWAAAA	CT	65.5	22.6
			CSW/S	CT	51.3	17.7
			AAAAA	--	25.2	8.7
4	123	7.9	CSWM	CT	39.9	32.4
			CSW/S	CT	37.1	30.2
			CSWS	CT	36.9	30.0
			AAAA	--	9.1	7.4
5	241	3.8	CSW/S	CT	241.0	100.0

[a]All tillages are performed in a vertical direction unless otherwise directed.

[b]CSW/S = Corn, soybeans, wheat/double cropped soybeans
CSWM = Corn, soybeans, wheat, meadow
CCSWAAAA = Corn, corn, soybeans, wheat, 4 years alfalfa
AAAAA = permanent alfalfa hayland

[c]CT = Conventional tillage
RT = Reduced tillage

[d]Plowed on the contour.

Table 2. Crop Rotations and Tillages for Each Representative Farm for Each Period and Each Soil Group[a].

Farm Number and Policy Scenario[b]	Average Annual Soil Erosion (T/ac.yr.)	Soil Group	Acre	PERIOD 1	2	3-5
		A	34	CSW/S-NT	CSW/S-NT	CSW/S-
1 Without RCWP	0.90	B	332	CSW/S-NT	CSW/S-NT	CSW/S-
		C	158	AAAAA	AAAAA	AAAAA
		D	474	CSWM-NT	CSWM-NT	CSWM-N
		A	34	CSW/S-NT	CSW/S-NT	CSW/S-
1 With RCWP	0.98	B	332	CSW/S-NT	CSW/S-NT	CSW/S-
		C	158	CCSWAAAA-NT	AAAAA	AAAAA
		D	474	CSWM-NT	CSWM-NT	CSWM-N
		A	86	CS-RT	CS-RT	c
		B	175	CSW/S-NT	CSW/S-NT	CSW/S-
2 Without RCWP	1.70	C	36	AAAAA	AAAAA	AAAAA
		D	32	AAAAA	AAAAA	AAAAA
		E	43	AAAAA	AAAAA	AAAAA
		F	44	AAAAA	AAAAA	AAAAA
		A	86	CSW/S-NT	CS-RT	c
		B	175	CSW/S-NT	CSW/S-NT	CSW/S-
2 With RCWP	1.64	C	36	CCSWAAAA-NT	AAAAA	AAAAA
		D	32	CCSWAAAA-NT	AAAAA	AAAAA
		E	43	CCSWAAAA-NT	AAAAA	AAAAA
		F	44	CSWM-NT	AAAAA	AAAAA
		A	22	CS-RT	CS-RT	CS-RT
		B	38	CS-RT	CS-RT	CS-RT
3 Without RCWP	1.06	C	106	AAAAA	AAAAA	AAAAA
		D	6	AAAAA	AAAAA	AAAAA
		E	118	AAAAA	AAAAA	AAAAA
		A	22	CS-NT	CS-RT	CS-RT
		B	38	CS-NT	CS-RT	CS-RT
3 With RCWP	1.16	C	106	CCSWAAA-NT	AAAAA	AAAAA
		D	6	CCSWAAA-NT	AAAAA	AAAAA
		E	118	CSWM-NT	AAAAA	AAAAA
		A	16	CSW/S-NT	CSW/S-NT	CSW/S-N
		B	7	CS-NT	CS-NT	CS-NT
4 Without RCWP	1.02	C	7	AAAAA	AAAAA	AAAAA
		D	29	AAAAA	AAAAA	AAAAA
		E	55	AAAAA	AAAAA	AAAAA
		F	9	AAAAA	AAAAA	AAAAA

(continued on next page)

Table 2 (continued)

Farm Number and Policy Scenario	Average Annual Soil Erosion (T/ac.yr.)	Soil Group	Acre	PERIOD 1	2	3-5
		A	16	CSW/S-NT	CSW/S-NT	CSW/S-NT
		B	7	CSW/S-NT	CS-RT T	d
4 With RCWP	1.13	C	7	CCSWAAAA-NT	AAAAA	AAAAA
		D	29	AAAAA	AAAAA	AAAAA
		E	55	CCSWAAAA-NT	AAAAA	AAAAA
		F	9	CSWM-NT	AAAAA	AAAAA
		A	110	CSW/S-NT	CSW/S-NT	CSW/S-NT
5 Without RCWP	0.98	B	5	AAAAA	AAAAA	AAAAA
		C	126	CSW/S-NT	CSW/S-NT	CSW/S-NT
		A	110	CSW/S-NT	CSW/S-NT	CSW/S-NT
5 With RCWP	0.99	B	5	CCSWAAAA-NT	AAAAA	AAAAA
		C	126	CSW/S-NT	CSW/S-NT	CSW/S-NT

[a]CT = Conventional Tillage
RT = Reduced Tillage
NT = No Tillage

[b]The same crop rotations and tillages were selected for all three interest rates.

[c]70.4 acres in CS-RT and 15.6 acres in CSW/S-NT.

[d]6.7 acres in CS-RT and 0.3 acres in CSW/S-NT.

Table 3. Initial Crop Yields[a] for Each Soil Group on the Representative Farms in the Representative Farms in the Highland Silver Lake Watershed (in bush acre except where indicated).

Soil Group	Corn	Soybeans	Double Cropped Soybeans[b]	Winter Wheat	Clover (Tons/Acres)	Alfalfa (Tons/Acr
1A	96	34	20	55	3.2	4.4
1B	114	40	24	61	3.0	4.3
1C	77	28	17	48	2.6	3.8
1D	52	21	13	37	2.1	2.6
2A	118	40	24	61	3.9	5.2
2B	114	40	24	61	3.0	4.3
2C	81	29	17	46	3.2	3.9
2D	34	13	8	18	1.2	1.7
2E	77	28	17	47	2.6	3.8
2F	49	20	12	35	2.1	2.5
3A	153	50	30	68	4.3	5.6
3B	125	44	26	59	3.0	4.1
3C	77	28	17	48	2.6	3.8
3D	33	12	7	17	1.2	1.6
3E	50	22	13	37	2.0	2.7
4A	148	54	32	72	4.3	5.2
4B	43	18	11	32	2.0	2.3
4C	51	18	11	25	1.7	2.3
4D	88	32	19	57	3.4	4.6
4E	100	35	21	59	3.7	4.9
4F	43	18	11	32	2.0	2.3
5A	114	40	24	61	3.0	4.3
5B	35	13	8	19	1.2	1.7
5C	76	28	17	48	2.6	3.5

[a]Obtained from Soil Conservation Service Technical Guide, Section II D supplement for Madison County, 1982.
[b]Estimated to be 60% of the full season soybean yield.

Table 4: Corn Yields Over Time for Each Rotation[a] and Tillage[b] for Soil Group 3A[c] on Representative Farms in the Highland Silver Lake Watershed (bushels/acre).

Rotation/ Tillage	Erosion	Year 10	20	30	40	50	Mean
CS/CT	6.02	152.89	152.78	152.66	152.54	152.43	152.7
CS/RT	3.37	152.94	152.88	152.81	152.74	152.68	152.84
CS/NT	1.47	152.97	152.95	152.92	152.89	152.86	159.93
CSWS/CT	4.40	152.92	152.84	152.75	152.67	152.58	152.7
CSWS/RT	2.20	152.96	152.92	152.88	152.83	152.79	152.90
CSWS/NT	0.73	152.99	152.97	152.96	152.94	152.93	152.9
CSWM/CT	2.64	152.95	152.90	152.85	152.80	152.75	152.8
CSWM/RT	1.32	152.98	152.95	152.93	152.90	152.87	152.9
CSWM/NT	0.73	152.99	152.97	152.96	152.94	152.93	152.9
CCSWAAAA/CT	2.05	152.96	152.92	152.88	152.84	152.80	152.9
CCSWAAAA/RT	1.17	152.98	152.96	152.93	152.91	152.89	152.9
CCSWAAAA/NT	0.44	152.99	152.92	152.98	152.97	152.96	152.9
AAAAA/ALL[d]	0.19	153.00	152.99	152.99	152.99	152.98	152.9

[a]Rotations: CS = corn-soybeans; CSWS = corn-soybeans-winter wheat - double cropped soybeans; CSWM = corn-soybeans-winter wheat-clover; CCSWAAAAA = corn-corn-soybeans-winter wheat - four years of alfalfa; AAAAA = five years of alfalfa.
[b]Tillages: CT = conventional tillage; RT = reduced tillage; NT = no-tillage; ALL = all tillages.
[c]Initial corn yield is 153.0 bu/acre.
[d]Values represent potential corn yields over time at that soil erosion level.

Table 5: Corn Yields Over Time for Each Rotation[a] and Tillage[b] for Soil Group 4D[c] on Representative Farms in the Highland Silver Lake Watershed (bushels/acre).

Rotation/ Tillage	Erosion	Year 10	20	30	40	50	Mea
CS/CT	47.05	78.24	75.76	74.08	72.40	70.73	75.2
CS/RT	26.40	80.13	77.44	76.21	75.27	74.33	77.4
CS/NT	11.48	81.50	80.33	79.16	77.99	76.94	79.6
CSWS/CT	34.43	79.39	76.61	75.38	74.16	72.93	76.5
CSWS/RT	17.22	80.97	79.22	77.47	76.55	75.94	78.6
CSWS/NT	5.74	82.02	81.44	80.86	80.27	79.69	81.1
CSWM/CT	20.66	80.66	78.55	76.81	76.07	75.33	78.1
CSWM/RT	10.33	81.60	80.55	79.50	78.34	77.40	79.97
CSWM/NT	5.74	82.02	81.44	80.86	80.27	79.69	81.12
CCSWAAAA/CT	16.07	81.08	79.44	77.81	76.71	76.14	78.80
CCSWAAAA/RT	9.18	81.71	80.77	79.84	78.90	77.97	80.20
CCSWAAAA/NT	3.44	82.23	81.88	81.53	81.22	80.83	81.69
AAAAA/ALL[d]	1.49	82.41	82.26	82.11	81.96	81.81	82.

[a]Rotations: CS = corn-soybeans; CSWS = corn-soybeans-winter wheat - double cropped soybeans; CSWM = corn-soybeans-winter wheat-clover; CCSWAAAAA = corn-corn-soybeans winter wheat - four years of alfalfa; AAAAA = five years of alfalfa.

[b]Tillages: CT = conventional tillage; RT = reduced tillage; NT = no-tillage; ALL = all tillages.

[c]Initial corn yield is 88.0 bu/acre.

[d]Values represent potential corn yields over time at that soil erosion level.

Table 6: Corn Yields Over Time for Each Rotation[a] and Tillage[b] for Soil Group 2D[c] on Representative Farms in the Highland Silver Lake Watershed (bushels/acre).

Rotation/ Tillage	Erosion	Year 10	20	30	40	50	Mean
CS/CT	54.34	25.87	25.65	25.44	25.22	25.00	25.50
CS/RT	30.49	25.95	25.84	25.71	25.59	25.47	25.85
CS/NT	13.25	26.37	25.97	25.91	25.86	25.81	26.10
CSWS/CT	39.76	25.92	25.77	25.61	25.45	25.29	25.7
CSWS/RT	19.88	26.00	25.92	25.84	25.76	25.68	25.99
CSWS/NT	6.63	26.81	26.32	25.99	25.96	25.94	26.32
CSWM/CT	23.86	25.98	25.89	25.79	25.69	25.60	25.93
CSWM/RT	11.93	26.46	25.98	25.93	25.88	25.83	26.13
CSWM/NT	6.63	26.81	26.32	25.99	25.96	25.94	26.32
CCSWAAAA/CT	18.56	26.02	25.93	25.85	25.78	25.70	26.0
CCSWAAAA/RT	10.60	26.55	25.99	25.94	25.90	25.86	26.17
CCSWAAAA/NT	3.98	26.99	26.69	26.40	26.11	25.99	26.55
AAAAA/ALL[d]	1.72	27.14	27.01	26.88	26.76	26.63	26.94

[a]Rotations: CS = corn-soybeans; CSWS = corn-soybeans-winter wheat - double cropped soybeans; CSWM = corn-soybeans-winter wheat-clover; CCSWAAAAA = corn-corn-soybeans-winter wheat - four years of alfalfa; AAAAA = five years of alfalfa.
[b]Tillages: CT = conventional tillage; RT = reduced tillage; NT = no-tillage; ALL = all tillages.
[c]Initial corn yield is 34.0 bu/acre.
[d]Values represent potential corn yields over time at that soil erosion level.

Table 7: Total Discounted Net Returns[a] for Each Hypothetical Farm for Fifty Years at Three Discount Rates ($/farm).

Farm Number and Policy Scenario[b]	Discount Rate		
	0%	7%	15%
1 without RCWP	3,025,406	787,684	407,238
1 with RCWP	3,172,021	888,322	480,821
2 without RCWP	1,910,078	497,441	257,204
2 with RCWP	1,965,345	535,377	284,941
3 without RCWP	605,682	157,693	81,528
3 with RCWP	636,920	179,135	97,206
4 without RCWP	647,204	168,504	87,118
4 with RCWP	656,145	174,641	91,605
5 without RCWP	1,014,614	264,160	136,569
5 with RCWP	1,052,328	290,048	155,497

[a]Rounded to nearest whole dollar.

[b]C = Soil erosion constrained to legal maximums in each period.
U = Soil erosion unconstrained in each period.
A = Cost share payments included in model.
No letter = no cost share payments included in model.

Table 8: Average Annual Discounted Net Returns per Acre for Each Hypothetical Farm at Three Discount Rates ($/acre/year).

Farm Number and Policy Scenario[a]	Discount Rate 0%	7%	15%
1 without RCWP	60.63	15.78	8.16
1 with RCWP	63.57	17.80	9.64
2 without RCWP	91.83	23.92	12.37
2 with RCWP	94.49	25.74	13.69
3 without RCWP	41.77	10.88	5.62
3 with RCWP	43.92	12.35	6.70
4 without RCWP	105.24	27.40	14.16
4 with RCWP	106.69	28.40	14.90
5 without RCWP	84.20	21.92	11.33
5 with RCWP	87.33	24.07	12.90

[a]C = Soil erosion constrained to legal maximums in each period.
U = Soil erosion unconstrained in each period.
A = Cost share payments included in model.
No letter = no cost share payments included in model.

Table 9: Total Soil Erosion[a] for Each Representative Farm for Fifty Years at Three Discount Rates (tons/farm).

Farm Number and Policy Scenario[b]	Discount Rate		
	0%	7%	15%
1 without RCWP	45,120	45,120	45,120
1 with RCWP	49,070	49,070	49,070
2 without RCWP	35,346	35,346	35,346
2 with RCWP	34,045	34,045	34,045
3 without RCWP	15,360	15,360	15,360
3 with RCWP	16,906	16,906	16,906
4 without RCWP	6,309	6,309	6,309
4 with RCWP	6,942	6,942	6,942
5 without RCWP	11,840	11,840	11,840
5 with RCWP	11,925	11,925	11,925

[a]Rounded to nearest ton.

[b]C = Soil erosion constrained to legal maximums in each period.
U = Soil erosion unconstrained in each period.
A = Cost share payments included in model.
No letter = no cost share payments included in model.

Table 10: Average Annual Soil Erosion per Acre for Each Hypothetical Farm at Thre Discount Rates (tons/acre/year).

Farm Number and Policy Scenario[a]	Discount Rate 0%	7%	15%
1 without RCWP	0.90	0.90	0.90
1 with RCWP	0.98	0.98	0.98
2 without RCWP	1.70	1.70	1.70
1 with RCWP	1.64	1.64	1.64
3 without RCWP	1.06	1.06	1.06
3 with RCWP	1.16	1.16	1.16
4 without RCWP	1.02	1.02	1.02
4 with RCWP	1.13	1.13	1.13
5 without RCWP	0.98	0.98	0.98
5 with RCWP	0.99	0.99	0.99

[a]C = Soil erosion constrained to legal maximums in each period.
U = Soil erosion unconstrained in each period.
A = Cost share payments included in model.
No letter = no cost share payments included in model.

Table 11: Total Net Returns[a] Per Period at the Zero Percent Discounting Rate for Representative Farm 2 ($/Farm).

Period	No Cost-Sharing	Cost-Sha
1	382,172	437,4
2	382,172	382,1
3	381,975	381,9
4	381,975	381,9
5	381,975	381,9

[a]Rounded to nearest whole dollar.

Table 12: Total and Per Acre Annual Net Returns and Soil Erosion for All Sensitivity Analyses Performed on Representative Farm 3 at 0% Discount Rate.

Scenario[a]	Total net Returns ($/farm)[b]	Average Net Returns ($/A/Yr)	Total Soil Erosion (T/Farm)[c]	Average Soil erosion (TAY)
3 without	605,682	41.77	15,360	1.06
3 with	636,920	43.92	16,906	1.16
3 without I	504,948	34.82	30,983	2.14
3 with I	549,775	37.90	23,256	1.60
3 without II	462,124	31.87	46,168	3.18
3 with II	508,552	35.07	37,156	2.56

[a]Without = No cost share payments.
With = With RCWP cost share payments.
I = Price of alfalfa hay decreased by 10%.
II = I plus no-till yields reduced by 5%.

[b]Rounded to nearest dollar.

[c]Rounded to nearest ton.

Table 13: Crop Rotations and Tillages[a] for All Sensitivity Analyses Performedon Hypothetical Farm 3

Farm Number and Policy Scenario[b]	Soil Group	Period				
		1	2	3	4	5
	A	1R	1R	1R	1R	1R
	B	1R	1R	1R	1R	1R
3 Without I	C	2N	2N	2N	2N	2N
	D	c	d	5	5	5
	E	3N	3N	3N	3N	3N
	A	1N	1R	1R	1R	1R
	B	1N	1R	1R	1R	1R
3 With I	C	2N	2N	2N	2N	2N
	D	c	d	5	5	5
	E	3N	3N	3N	3N	3N
	A	1R	1R	1R	1R	1R
	B	1R	1R	1R	1R	1R
3 Without II	C	1R	e	f	2R	2R
	D	c	d	5	5	5
	E	3N	3N	3N	3N	3R[h]
	A	1N	1R	1R	1R	1R
	B	1N	1R	1R	1R	1R
3 With II	C	5	e	f	2R	2R
	D	c	d	5	5	5
	E	3N	3N	3N	3N	3R

[a]1 = CS 3 = CSWM 5 = MMMMM
2 = CSW/S 4 = CCSWMMMM N = NT
C = CT R = RT

[b]Without = No cost share payments.
With = With RCWP cost share payments.
I = Price of alfalfa by decreased by 10%.
II = I plus no-till yields reduced by 5%.

[c]4.7 acres in 2N and 1.3 acres in 4N.

[d]1.2 acres in 3N and 4.8 acres in 5.

[e]23.3 acres in 1R and 82.7 acres in 2R.

[f]11.3 acres in 1R and 94.7 acres in 4R.

[g]75 acres contour plowed.

[h]68 acres contour plowed.

SOIL LOSS TOLERANCE: AN OVERVIEW

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The concept of soil loss tolerance is very important. In order to do farm planning with the Universal Soil Loss Equation, it is necessary to set a limit of soil loss that can be tolerated. For many years we assumed that we know approximately how much this was. However, within the last two or three years, the economists have asked us to show them a scientific basis for soil loss tolerance. We were not prepared to do this. We did not have scientific evidence for many of the assumptions we had made over the years.

Until very recently, we had based soil loss tolerance on the amount of topsoil loss. Realizing that topsoil is normally better than subsoil as a medium for seed germination and early seedling growth, we felt that damage to the soil through loss of topsoil is much more important when the underlying B horizon is of very poor physical or chemical condition due to high clay content or high aluminum or for some other reason. Another factor considered very important was potential rooting depth. If the material of the soil profile is bedrock or very compact till into which roots cannot enter, plants like corn and soybeans will not be able to draw enough water for maximum productivity. Crop damage due to high soil losses and loss of pesticides and fertilizers has also been a consideration.

Recently, the emphasis has shifted to effect on water quality of sediment and losses of various chemicals. It has been suggested that a T-value be developed for these. This is a new ballgame as far as factors involved. At any rate, the T-factor deserves another look because of newer developments in our view of what is most important.

Evolution of the T-Value

The concept of soil loss tolerance was introduced in the early 1940's and again at a joint conference on slope practice in 1956. This 1956 conference was attended by USDA Agriculture Research Service and Soil Conservation Service personnel and by people from various universities. At this conference, a set of criteria were developed for determining soil loss tolerance. These criteria were: a) maintenance of an adequate soil depth for crop production; b) value of nutrients lost; c) maintenance of water control structures (e.g. open ditches, ponds, reservoirs, terrace channels) and the control of flood plain sedimentation; d) prevention of gullies; e) crop yield reduction (per inch of topsoil loss); f) water losses; and g) seedling losses.

Although soil loss tolerance could be lower, 5 tons per acre was shown as the upper limit, it will be noted that the above criteria include the concept of adequate soil depth, nutrient loss, offsight damage, erosion control to

prevent serious damage as by gullies, crop yield reduction, and seedling losses.

Current criteria as developed by the Soil Conservation Service (SCS) are summarized by McCormack and Young of SCS and are: a) an adequate rooting depth must be maintained for plant growth. Soils with impervious B horizons are given lower T-values than those with deep permeable subsoils. b) Soils that have significant yield reductions, if the surface layer is removed by erosion, are given lower T-values than soils that have only minor yield reductions if the surface is removed.

It will be noted that the above criteria give greatest emphasis to long term soil productivity caused by either reduction in potential rooting depth or loss of topsoil. Gully erosion or annual losses of crop, nutrients, and pesticides are not considered.

There have been some attempts to alter the T-values originally given to soils in the United States, but these have been unsuccessful. One attempt was actually proposed by the SCS. Criticism from other agencies and organizations was so great that SCS decided to take another look before proceeding. According to McCormack and Young of SCS (1980), the maximum T-value of 5 tons/acre has been selected for the following reasons:

1. Soil losses in excess of five tons per acre affect the maintenance, cost and effectiveness of water control structures that can be damanged by sediment.

2. Excessive sheet erosion is accompanied by gully formation in many places.

3. Loss of plant nutrients is considered excessive.

4. On most soils, conservation practices can keep soil erosion below five tons per acre per year.

My own recommendation has been that since soil losses greater than 5 tons per acre per year give evidence of rilling along with loss of shallow or surface applied fertilizer and pesticides and damage to seedlings as well as offsite damages, the present "T" values should not be raised above 5 tons. While this judgement is subjective and observational rather than scientifically based, it is one that is subscribed to by many people who have experience in soil erosion. Present work by ARS with the EPIC (Erosion-Productivity Impack Calculator) model (Williams et. al. 1983 and by Kiniry et. al. 1983) should result in a more scientific basis for the foregoing as well as depletion of topsoil and rooting depths.

On many soils and under many conditions, an A horizon renewal rate can take place at 5 tons per acre per year, or an inch in 30 years. If residues are returned each year, then some B horizon can be assimilated into the plow layer without causing a great loss of productivity. Rooting depth, however,

is a different story. Usually the potential rooting depth increases at an extremely low rate and renewal is of very little consequence. This is obviously true if the soil profile is underlain by bedrock, but it can be equally serious when the soil profile is underlain by very dense materials such as compact glacial till.

As a sidelight, there is evidence that the deleterious effect of farming B horizon is not as great with no-till as it is with moldboard plowing. Much of the damage of plowing up B horizon, especially one with high clay, is the fact that with moldboard plowing the seedbed can be very clodly and undesirable for germination and seedling growth. This does not happen in no-till since there is practically no tillage involved except a slot for the seed, and the mulch keeps the soil surface from drying out.

The evidence today points to the fact that much of the concern of society for soil loss is from offsite damages. From this, it would appear that soil loss tolerance based on offsite damages (Larson's T_2) will become at least as important, if not more important, than damage to long-term productivity of the soil. There has not been enough emphasis on T_2 values to induce research people to work on the criteria involved in assigning tolerance values for this reason. Factors important here are the position of a field on the watershed and how directly this field contributes to a major drainageway. There will be a great deal more onsite input required for T_2 than for T values. However, until societal pressure becomes much greater, nothing will likely be done.

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SOIL LOSS TOLERANCE AND WATER QUALITY FIELD STUDY

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Introduction

Initial water quality management planning efforts documented that agricultural activities are a major source of pollution in Illinois and mandated the development of plans to control this nonpoint source pollution from agriculture. The most severe agriculturally related problem identified was soil erosion and its effects upon the aquatic environment.

Nationwide, approximately half of the total sediment delivered to lakes and streams is from cropland. In Illinois estimated gross erosion exceeds 180 million tons annually, with 158 million tons from sheet and rill erosion from cropland (IEPA, 1979).

In Illinois, erosion control is being used as surrogate for sediment control because sediment control is less amendable to quantitative analysis. The idea of using erosion control as a surrogate for sediment control reflects the current lack of knowledge concerning sediment origin, transport, deposition, and control technology.

It is important to note that soil erosion is not synonymous with soil loss, nor is soil loss equal to sediment yield. The Illinois Erosion and Sediment Control Program (IDOA, 1980) goal is to reduce soil losses until there is no land in the State with long-term average annual soil erosion losses exceeding the soil loss tolerance ("T") established for maintaining soil productivity. A number of interim goals were established to help track progress toward achieving this goal. These goals are based on multiples of the soil's "T" value.

The Illinois Environmental Protection Agency (IEPA) in cooperation with United States Department of Agriculture Agencies, Agricultural Stabilization and Conservation Service (ASCS), Illinois Cooperative Extension Service (CES) and Soil Conservation Service (SCS), is evaluating the impact of Resource Management Systems (RMS's) implemented under the Agricultural Conservation Program-Special Water Quality Project in the Blue Creek Watershed, Pike County, Illinois. The Illinois State Water Quality Survey was contracted to complete certain components (streamflow measuring and loading calculations) of this project. The primary objective of this project is to identify the most viable agricultural nonpoint source (NPS) control strategy, demonstrate its effectiveness, and develop a methodology to identify land causing water quality problems and to determine the appropriate RMS for the identified land. The purpose of this report is to present and interpret water quality data collected from two field sites as part of the Blue Creek Watershed Project and report the findings of the computer simulation concerning effectiveness of RMS's.

Description of Blue Creek Watershed

The Blue Creek Watershed encompasses 7,012 acres in east central Pike County, Illinois. It drains into Pittsfield City Lake through Blue Creek and its numerous tributaries (refer to Figure 1). The Blue Creek Watershed is located approximately three miles northwest of Pittsfield and five miles south of Griggsville.

Pittsfield City Lake was constructed in 1961 by SCS as a multiple purpose reservoir. It is utilized for recreation, flood control, and as a water supply for the city of Pittsfield. There are no known municipal or industrial discharges to the Blue Creek Watershed upstream from Pittsfield City Lake.

The land use in Blue Creek Watershed is predominantly agricultural. The cultivation of row crops and production of livestock are important in the watershed. The predominant crop in the watershed is corn (47.7 percent of the acreage in cropland). Soybeans, wheat, and grasses are also important crops. The terrain is hilly, and it has a high soil loss potential due to its steep slopes, fine-textured soils and agricultural land use practices. There are approximately 460 acres of hog and cattle feedlot operations on 21 farms. For a more detailed description of Blue Creek Watershed and Pittsfield City Lake refer to Blue Creek Watershed Project, May 1979-October 1980, (Davenport, 1981).

Monitoring and Evaluation

Methods used for field and laboratory procedures are those accepted for agricultural related hydrology research.

There were two field cropland monitoring sites in the Blue Creek Watershed. These sites are sampled only on event-runoff basis.

Station E

Station E (see Figure 2) is located in the northwestern part of the watershed. Runoff resulting from rainfall-events and snowmelt is sampled at Station E.

Station E consists of one 38-acre field draining into an unnamed channel. Table 1 lists the past practice, present practice and the average annual erosion rate by practice. The present practice has reduced average annual erosion by 60 percent. This soil loss is still approximately 2 times the allowable maximum soil loss per acre tolerance loss (T) a given soil may experience and still maintain its productivity over an extended period of time as defined by SCS.

Station F

Station F (See Figure 3) is located in the northern part of the watershed. Runoff resulting from rainfall events and snowmelt is sampled at Station F.

Drainage area of Station F consist of 78 acres draining four different fields. Table 2 lists the past and proposed practices and the average annual erosion rate by practice for each field. The implementation of proposed practices will reduce average annual erosion by 77 percent. The resulting soil loss is below the maximum allowable soil loss tolerance per acre (T).

Sediment Concentrations

On October 5, 1981 a rainfall-runoff event was measured at both field sites. Refer to the Status of Agricultural Activities on the Field Sites subsection to determine the condition of the individual field site during the October 5, 1981 storm event. Total precipitation basin-wide 1.52 inches, at the rain gauge closest to Site E and F 1.82 inches was measured (Figures 2 and 3).

Site F is a (78 ac.) drainage area consisting of four fields under various management conditions whose average annual soil erosion is less than 5.0 tons/acre, which is the ultimate goal of the State Soil Erosion and Sediment Control Program (IDOA, 1980). Site E is managed so average annual soil erosion would be approximately 10 tons/acre (twice the ultimate goal). Station F had significantly higher TSS and TVS concentrations in comparison to Station E. Site F's drainage area had a significant percentage of cropland in soybeans during 1981. Field 4 was in soybeans it serves as the headwaters for Site F's drainage. Soybeans produce less crop residue than corn and contribute 60 percent less organic material to the soil. Soils with less organic matter hold less moisture and are more susceptible to detachment by raindrop. It is important to note that mega rill was observed on Field 4 at the headwaters of the drainage pattern.

The only other rainfall-runoff event where samples were collected for Stations E and F was July 3, 1982. Due to the insufficient sample size no statistical analysis could be completed.

The extreme variation in sediment concentrations from runoff-event to runoff-event and the lack of a complete data base illustrates the need to collect more information and to use computer simulations to determine the impact of various RMS's. Limited water quality data combined with the Status of Agricultural Activities indicates that the effectiveness of the RMS implemented various seasonally.

Sediment concentrations in Site E's runoff could cause offsite damage to the potential fisheries resource. The fisheries resource within the watershed is most vulnerable from late April to early July due to the spawning cycle (Thomas[1] personnel comm.) 63 percent of the measured runoff events had sediment concentrations in excess of the proposed limit of what is likely to

support a good fisheries resources. All of these events occurred at the time when the fisheries resource was most vulnerable. Of the events when mean sediment concentrations was below 200 mg/l only 1 occurred outside the April to July period. One-third of Site F's measured runoff events occurred during the April to July period and it just barely exceeded the 80 mg/l limit (NAS-NAE, 1972). This indicates that the "T" concept is not temporally related to potential water use impairments through the degradation of the biological integrity of the water resource. Sediment concentrations and loads can also have offsite inputs upon other water related resources and uses.

The TVS percentage of TSS did not exhibit a consistent pattern between storm event size, percent ground cover or field monitoring sites. Higher TVS/TSS values were measured after land management activities that distributed the ground cover. There was insufficient data to determine precise relationships between TVS/TSS ratios and individual land management activities.

Sediment Loading

Table 5 shows sediment load by measured runoff event for Field Sites E and F. There is a positive correlation between sediment load and runoff, this is expected due to the fact that runoff transports the sediment off the site. Hence reducing the runoff would reduce the sediment load.

From limited data, Field Site F. sediment loads were inversely correlated with percent cover. February 19, 1981, 53 percent residue cover was reported for the Site and sediment load was 1.1 tons, on July 3, 1982 canopy cover was 83 percent and sediment load was .03 tons.

Field Site E's cover/sediment load relationship was inconsistent. Cover during the May 5, 1981 storm was estimated to be 95 percent, sediment load was 9.3 tons. For the July 3, 1982 storm, cover was 95 percent, sediment load was estimated to be 0.3 tons; 3 percent of the May 5, 1981 load. Field Site E, total event precipitation is positively correlated with sediment load; the higher the rainfall the greater the sediment load.

CREAMS Simulation

Since a single design storm is inadequate to evaluate the effectiveness of best management practices to control pollution a three year period was simulated using measured precipitation. Chemical, Runoff, and Erosion from Agricultural Management Systems (CREAMS) was used to assess the impact of the present and projected erosion rates on the sediment and nutrient components of water quality. Table 6 summarizes sediment yield and rainfall-runoff ratio values abstracted from simulation runs for a three year period on different management options. Three management options were simulated; conventional tillage, chisel tillage, and a no-till system, potential soil erosion was 4"T", 2"T" and less than "T" respectively. The higher the rainfall-runoff ratio value the greater percentage of rainfall that would

result in runoff thus higher the soil particle transport capacity. Table 6 indicates that the conventional tillage option has a higher efficiency for transforming rainfall into runoff, than the chisel system and the no-till operation. Surface runoff from conservation tillage is about 12 percent less than the conventional tilled fields. Surface runoff from the no-till option is predicted to be about 20 percent less than that predicted from a conventional tilled field. This is considerably less than the 25 percent reported in the literature (Humenik, 1982; Baker, 1983). These discrepancies could result from using a short term simulation based upon actual precipitation, which was 5 percent below normal, being compared to long term research efforts.

Table 6 indicated no-till is extremely effective in reducing sediment yield in comparison to conventional tillage and reduced tillage operations. Literature (Burwell, 1983) shows soil loss reduction of 58 percent from conventional tillage to conservation tillage. In this simulation, no-till showed a decrease of 80 percent and conservation tillage of 12 percent. This is significantly less than Burwell's reported soil loss reduction. This discrepancy probably results from using short-term information and comparing it against long-term results. This results from reduced runoff, as indicated by the rainfall-runoff ratio, and reduction in both soil detachment and transport. The detachment of soil particles by rainfall is accomplished by two processes. The first involves dislodging soil as a result of the kinetic energy of rainfall. The second process involves the separation of particles from the soil mass by shear and lift forces generated by overland flow. No-till results in increased ground cover and infiltration, thus decreasing soil detachment and transport. The importance of soil surface protection from raindrop impact to achieve reduced sediment in runoff is clearly demonstrated in Figure 4.

Since sediment yield is reduced from conventional tillage levels by chisel and no-till operations, a corresponding decrease in nutrients associated with sediment can be expected. The percent reduction associated with switching management systems, varies between nitrogen and phosphorus.

In terms of nutrient export from Field Site E, the conventional system allowed the greatest transport 5.89 (P) and 16.09 (N) lbs/ac. Switching from the conventional system to the chisel system reduced P transport by 11 percent and N transport by 18 percent. Table 7 indicated the no-till management system is extremely effective in reducing P and N transport to the conventional and chisel system.

Losses of soluble P in runoff water were less than the losses of P transported by sediment (Table 7) except when the no-till management option was simulated, then the reverse is true. Losses of soluble N were greater than the losses of N associated with sediment under all simulated management options. The estimated losses of soluble and sediment associated nutrients strongly reflected the influence of vegetative cover on runoff and erosion among the soil cover conditions, resulting from the management activities, and seasonal precipitation patterns.

The simulations documented selective erosion was occurring, this process is a result of the energy limitations of the runoff and the availability of particular soil fractions to the runoff and detachment. The predicted sediment had a greater percentage of clay and organic matter than the parent soil. Nutrients and pesticides occur in highest concentrations on smaller sediment particles (i.e., clay and organic matter) because of their larger surface area to volume ratio (Humenik, 1982). The selective erosion phenomenon and the fact that polluting substances (nutrients and pesticides) have a greater affinity for the smaller particles cause the erosion process to remove the polluting substances preferentially.

Figure 5 shows the impact of various management options on the distribution of primary particles in the eroded sediment. No-till eroded sediment had the lowest composition of clay, sand, and organic matter, the chisel system produced sediment with the lowest average silt composition. By volume, the no-till and chisel system produced less clay and silt when compared to the conventional moldboard plow system.

Tables 6 and 7 clearly indicates that the management option which results in soil erosion potential is less than "T" (no-till) has significantly less sediment and nutrients leaving the site than the other two management options (chisel and conventional tillage). Reduction in soil delivery does not always produce visible improvements in water quality since silt and clay particles appear to be the hardest to control and yet contribute most to water and turbidity problems.

Conclusions

1. The extent of variation in sediment concentrations from runoff-event to runoff-event, illustrates the need for long term studies to document the impact of Resource Management Systems on loading of sediment.

2. Computer simulations indicated that the management option which reduced erosion to "T" value had significantly lower sediment and nutrient associated sediment yields than management conditions where the field was at 2 "T" and 4 "T".

3. Effectiveness of cultural practices varied by season, due to crop canopies and residue cover being seasonally dependent.

4. Limited water quality data did not indicate a strong correlation between sediment concentrations and level of management (i.e., 2 "T" or "T"). Therefore, soil loss tolerance standards must be developed for water quality purpose if they (soil loss tolerance standards) are going to be used as surrogate for sediment control standards.

5. Timing of runoff events (duration and frequency) and the resulting potential impact upon water resources are not related to "T" values. Soil loss tolerance standards that are implemented for water quality

purposes must take into consideration the biological integrity of the residual water resource.

6. Mega rill is an observed cropland erosion phenomena, but this process was not included in the determination of the "T" values for these soils.

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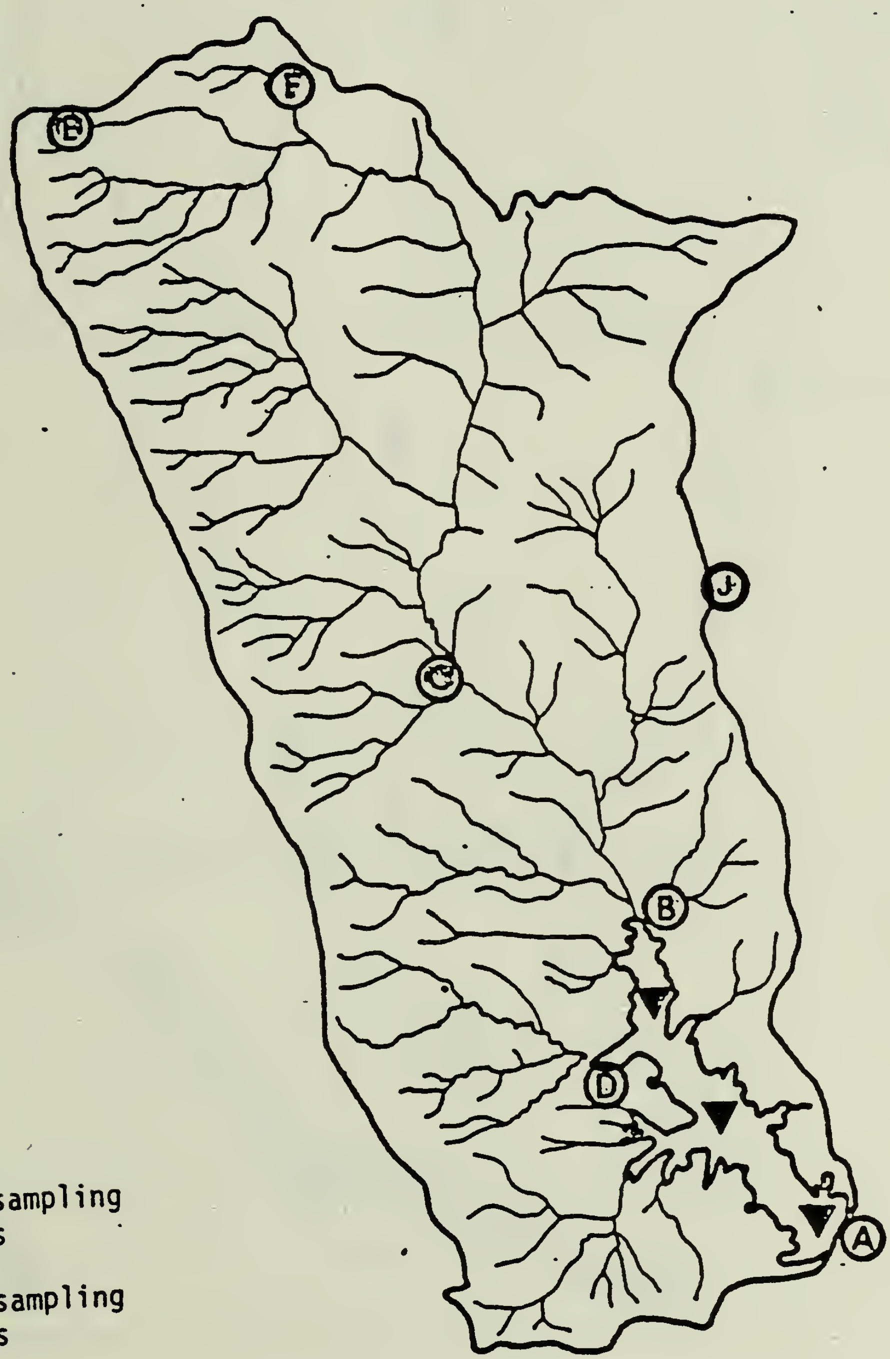
Figure 1. Map of Water Quality Stations in the Blue Creek Watershed in Pike County, Illinois



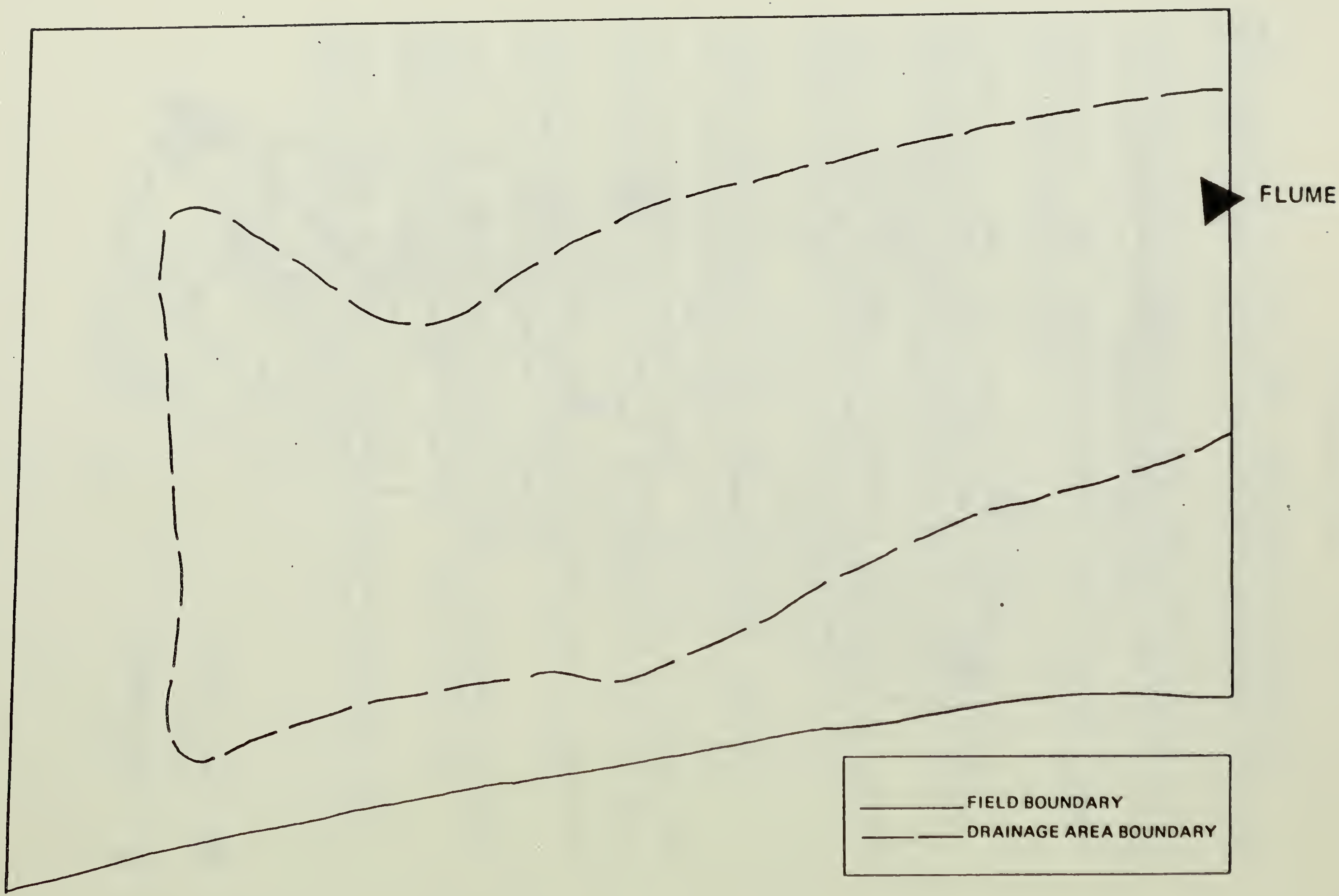


FIGURE 2, SITE E

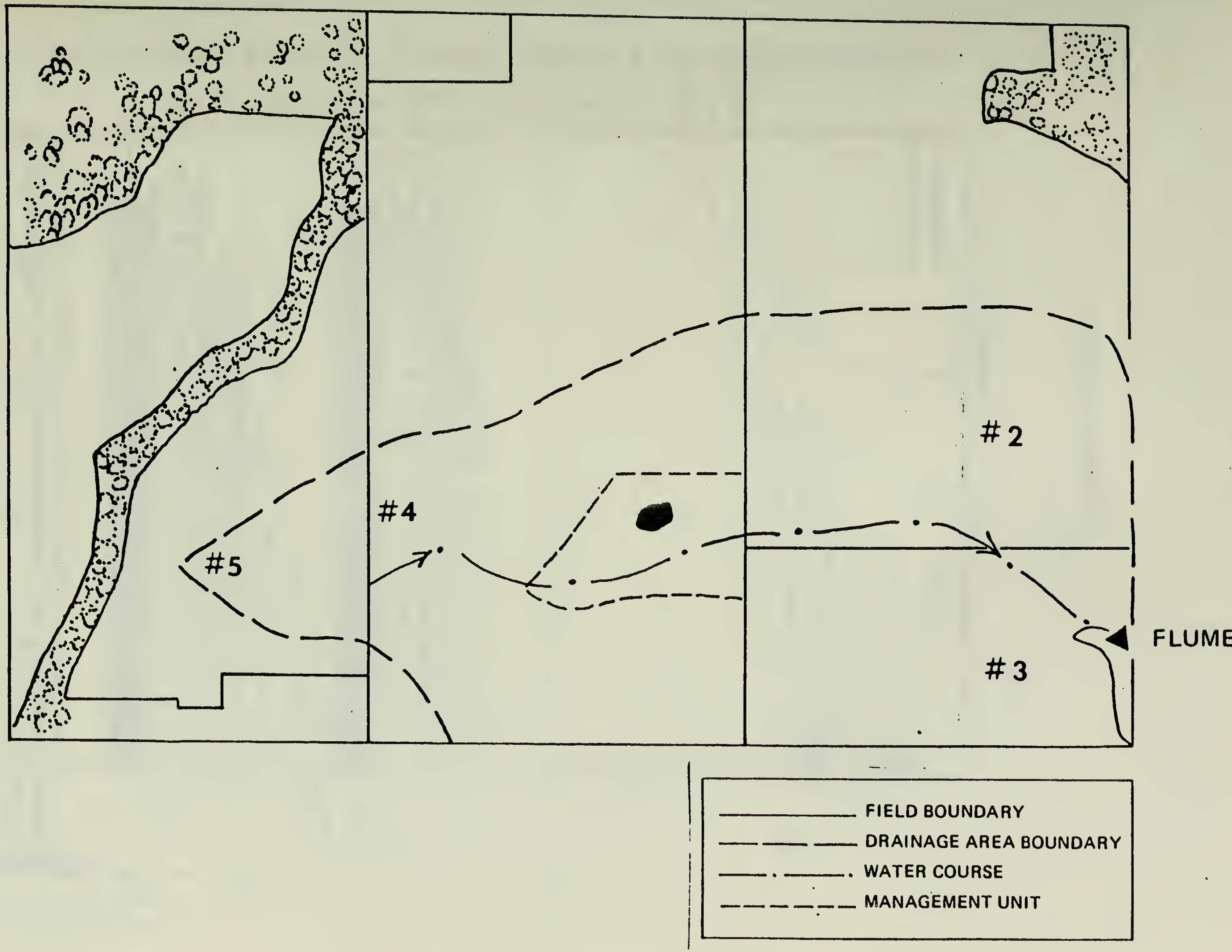
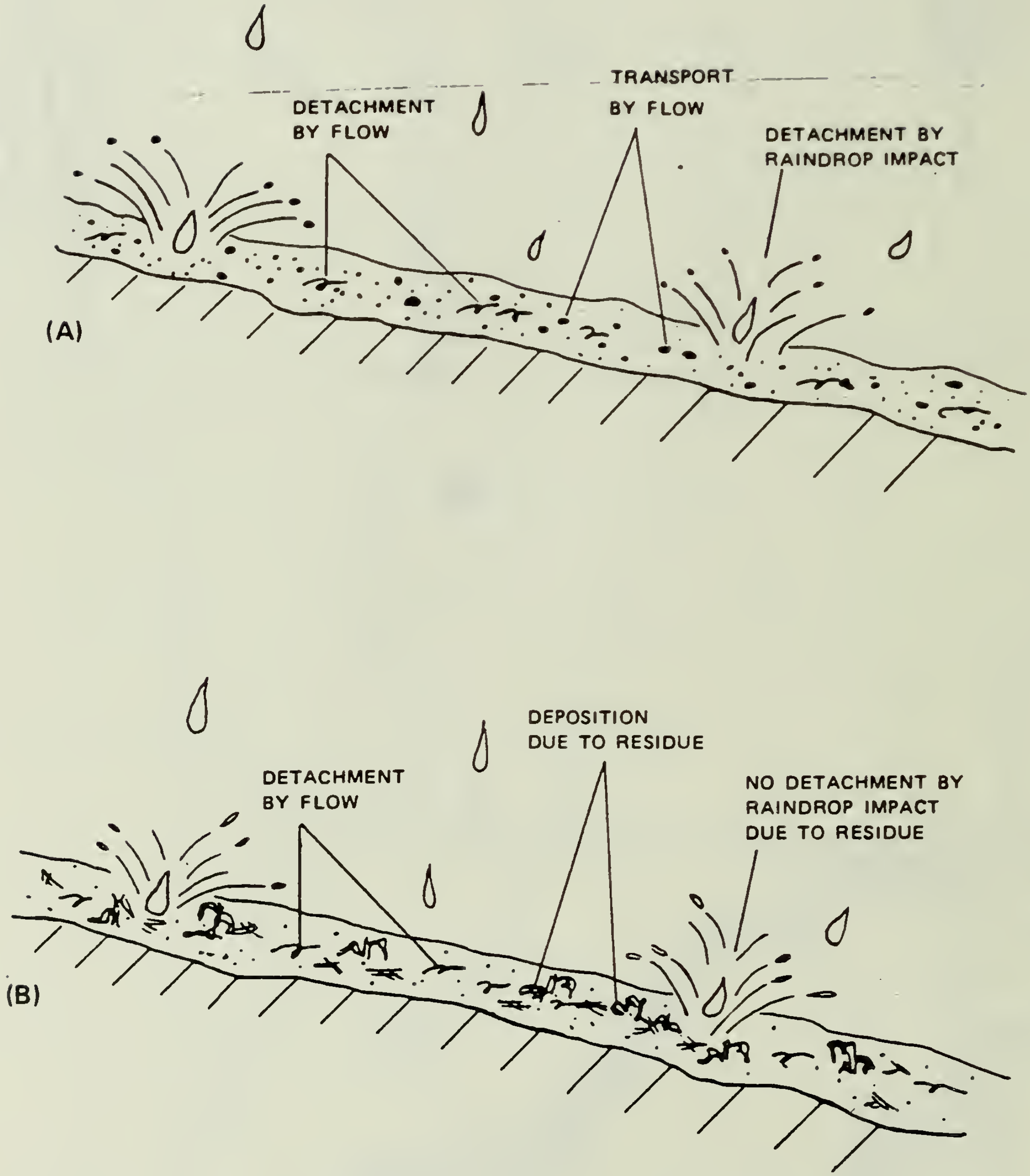


FIGURE 3, SITE F

FIGURE 4



Sediment Detachment and Transport on Bare (A) and Residue-covered (B) Ground During Rainfall.

FIGURE 5

AVERAGE DISTRIBTION OF PRIMARY PARTICLE IN ERODED SEDIMENT

FOR THREE MANAGEMENT OPTIONS ON SITE E

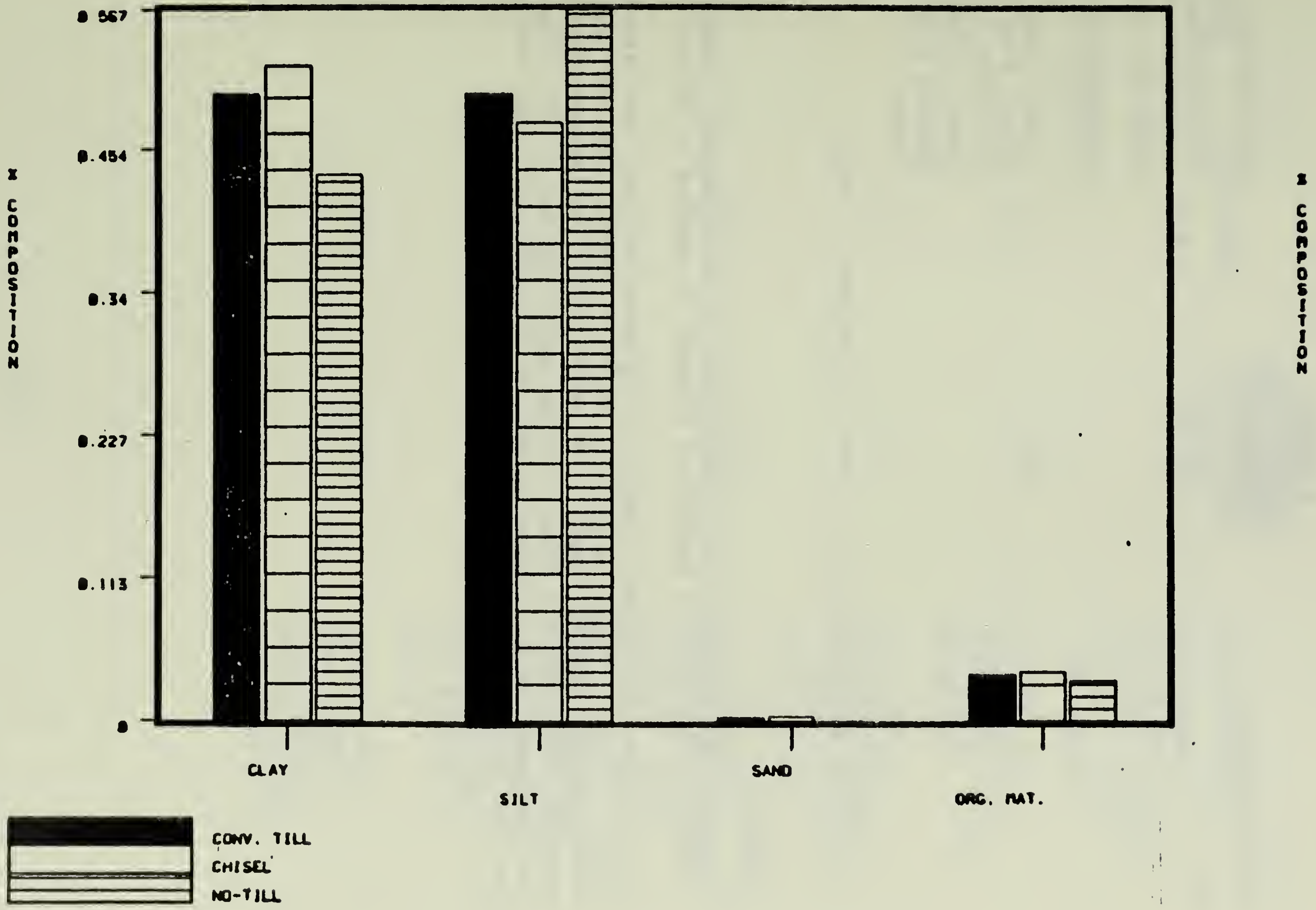


TABLE 1

Past practice, present practice and the associated average annual erosion rate by practice for Station E's drainage area.

SIZE (acres)	$\bar{X}$ ANNUAL EROSION RATE* (TONS/ACRES)	PAST PRACTICE
38	24 Tons	C-Sb Rotation Spring Plow Up & Down the Slope
		PROPOSED PRACTICE
	9.6	C-Sb-W Rotation Chisel Plow in the Fall Disk Twice & Plant; 1-2000 lbs. Residue Left on the Ground

*Calculated using the USLE C; Corn, Sb; Soybean, W; Wheat

Station F

Station F is located in the northern part of the watershed. Runoff resulting from rainfall events and snowmelt is sampled at Station F.

Drainage area of Station F consist of 79 acres draining four different fields. Table 2 lists the past and proposed practices and the average annual erosion rate by practice for each field. The implementation of proposed practices will reduce average annual erosion by 77%. The resulting soil loss is below the maximum allowable soil loss tolerance per acre (T).

TABLE 2

Past practices, proposed practices and the associated average annual erosion rate by practice for fields in Station F's drainage area.

FIELD NUMBER	SIZE (acre)	X̄ ANNUAL EROSION RATE* (TONS/ACRE)	PAST PRACTICES
#2	14.6	19-20	C-Sb Rotation Spring Plow Across the Slope or Disk - Chisel - Disk Twice - Plant
#3	19.8	10-11	C-Sb-W-4 yrs. Grass Rotation - Spring Plow Across the Slope
#4	34.1	19-20	C-Sb Rotation Spring Plow Across the Slope or Disk - Chisel - Disk Twice - Plant
#5	10.0	30-33	C-Sb Rotation Spring Plow Across the Slope or Disk - Chisel - Disk Twice - Plant
			PRESENT PRACTICES
#2	14.6	4.5-5.0	C-Sb-W Rotation Conservation Tillage 1-2,000 lbs. Residue on Contour
#3	19.8	3.5-4.5	C-Sb-W-7 Yrs. Grass Rotation - Conservation Tillage 1-2,000 lbs. Residue on Contour

FIELD NUMBER	SIZE (acre)	X ANNUAL EROSION RATE* (TONS/ACRE)	PRESENT PRACTICES
#4	34.1	4.5-5.0	C-Sb Rotation Conservation Tillage 1-2,000 lbs. Residue on Contour
#5	10.0	4.5-5.0	C-Sb Rotation Conservation Tillage 1-2,000 lbs. Residue on Contour with Grassed Back Slope Terrace

*Calculated using the USLE C; Corn, Sb; Soybean, W; Wheat

Status of Agricultural Activities on the Field Sites

TABLE 3

Site E; canopy cover is shown below. The wheat crop was planted first part of November, harvested first part of July.

Month	Percent cover	
April, 1981	75	canopy cover
May	95	
June	95	
July	85	harvest, residue cover
August	80	
September	80	
October	80	
November	50	
December	50	
January, 1982	50	
February	50	
March	50	
April	20	
May	20/15	residue/canopy
June	40	
July	95	
August	95	
September	85	
October	85	residue

Site F; crop varied by field. Field 3 was in pasture, field 4 was in soybeans and fields 2 and 5 were in corn. The only rainfall runoff event sampled at Site F occurred in October. Fields 2 and 5 had a canopy cover of 95%, field 4 had a residue cover of 60% and field 3 had ground cover of 95%.

TABLE 4

Crop canopy by field and month on Site F.

	Month	Type Cover (Fields 2 & 5)	% Cover (Fields 2 & 5)	Type Cover (Fields 3 & 4)	% Cover (Fields 3 & 4)
1981	November	residue	85	residue	20
	December		85		20
1982	January		85		20
	February		85		20
	March		85		20
	April		40		20
	May		40		11
	June	canopy	15	canopy	40
	July		70		95
	August		95		95
	September		70		95
	October	residue	70		90

1982 CROP = Fields 2 & 5 .. SOYBEANS
Fields 3 & 4 .. CORN

TABLE 5

Loading Summary by Event, by Field Site in Blue Creek Watershed, Pike County, Illinois (Lee, 1983)

Date (start of storm)	Precip. (inches)	Runoff (inches)	Sed. Load (tons)	Precip. (inches)	Runoff (inches)	Sed. Load (tons)
5/17/81	3.06	.75	9.282	-	-	-
10/05/81	1.82	.01	.002	-	-	-
10/17/81	-	-	-	0.95	.05*	N.A.
2/16/82	-	-	-	0.40	.13*	N.A.
2/19/82	-	-	-	0.56	.48	1.10
6/08/82	2.29	.05* (0.26)**	N.A. (0.51)**	2.29	.14	N.A.
7/03/82	1.44	.02	N.A. (0.26)**	1.44	.01	0.03
7/26/82	-	-	-	2.16	.55	N.A.

N.A. = insufficient water quality samples to estimate sediment load
* = incomplete hydrograph
** = estimated by IEPA personnel using limited data not by Lee (1983)

TABLE 6

Analysis of sediment yield, rainfall/runoff ratio and potential erosion by various agricultural management options for Site E as predicted through CREAMS simulations.

	"T" Erosion Valve	Runoff as % of rain	Tons of sediment/ac
Conventional tillage Sb-W-C Spring Moldboard Plow	4 T	13.5	5.58
Chisel Tillage Sb-W-C 30% residue	2 T	11.9	4.92
No-till; Sb 80% residue; C 30% residue; W	< T	10.7	1.15

TABLE 7

Analysis of nutrient yield by various agricultural management options for Site E as predicted through CREAMS simulations.

	Phosphorus Sediment	lbs/ac Runoff	Total	Nitrogen Sediment	Runoff	Total
Conventional tillage Sb-W-C Spring Moldboard Plow	3.42	2.47	5.89	6.66	9.43	16.09
Chisel Tillage 30% residue Sb-W-C	3.05	2.20	5.25	5.94	7.27	13.21
No-till Sb-W-C Sb - 80% residue; C disk 20% residue W	1.00	2.40	3.40	1.94	8.05	9.99

LAKE SEDIMENTATION IN ILLINOIS

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Illinois State Water Survey

Lake sedimentation is a major concern of water supply managers in central and southern Illinois. In these areas, groundwater sources are either very limited or nonexistent, and surface water sources are the primary source of public water supply. The primary impact of lake sediment is the loss of storage capacity in the reservoir as it fills with sediment. A major secondary impact of sediment accumulation in reservoirs is its affect on water quality. In some lakes with low sedimentation rates but high pollutant levels, water quality impacts may become the primary source of concern.

In its lake sedimentation program, the Illinois State Water Survey has conducted 170 lake sedimentation surveys on 125 lakes. The results of the program indicate sedimentation losses ranging from 0.2 percent per year to over 4 percent per year. Records of soil losses from the watershed are less complete but vary from less than 0.5 tons per acre per year to 6 tons per acre per year.

Concerns about the effects of lake sedimentation are not limited to public water suppliers.

- Those who run lake recreational facilities are aware of the effects sediment accumulations have on the recreational value of reservoirs (from damage to swimming facilities to lowering of water depths below levels needed for boating).

- Agronomists are concerned about lake sedimentation because of the loss of valuable topsoil and nutrients it represents in crop production.

- Biologists are concerned with the impact of sediment, whether suspended or deposited on aquatic biota.

- The impact of sediment on water quality is of concern because of the nutrients, trace metals, and organic compounds carried by the sediment.

- Finally, sedimentation affects policy makers because of the separation of the sources of sediment (agriculture, construction, mining, and urban areas) from the point of impact.

Lake sedimentation rates are generally defined in one of four ways. These are: (1) average annual volume of sediment per acre of watershed, (2) average annual tonnage of sediment per acre of watershed, (3) average annual loss of volume as a percentage of the original volume, and (4) average annual depth of sediment accumulation.

Lake sedimentation is a complicated process that is best described by a source to sink model. This simple model begins with a source: erosion from the watershed (by sheet, rill, or gully erosion) or streambank erosion. The sediment is then transported by a moving stream of water either in suspension or along the bed. Finally, the sediment-laden water reaches an area where the water slows and can no longer carry all of its sediment load. The largest sediments are no longer moved by the water and form permanent sediment deposits.

This simple model becomes more complicated when more basic factors are taken into account:

- Erosion rates are influenced by such factors as field slope, geology, soil types, land use, land cover, and volume, rate, and type of precipitation.

- Transport of sediment is influenced by channel slope, channel shape, channel roughness, amount of over bank flow, and volume and rate of runoff.

- Finally, the process of sediment deposition is influenced by the shape, age, capacity, and depth of the reservoir as well as by outflow rates, existence of either living or dead vegetation, and exposure of sediments to drying and compaction.

Several example based on recent Water Survey lake sedimentation studies will serve to illustrate the influences of these factors.

Pittsfield Lake

Pittsfield Lake serves as the water supply source for the city of Pittsfield, Illinois. A lake sedimentation survey was completed in 1979 with the assistance of the city and Benton and Associates, Engineers, of Jacksonville. The reservoir had previously been surveyed in 1974 by Benton and Associates.

Table 1 is a summary of the results of the 1974 and 1979 surveys. It shows that the lake lost 19.7 percent of its original capacity as a result of sedimentation between 1961 and 1979. Table 1 also shows a significant decease in the sedimentation rate from 1974 to 1979. This decrease may have resulted from a combination of several factors, such as a change in the trap efficiency of the lake, variations in stream peak flow, and improved soil conservation measures established in the watershed.

Table 2 shows the average annual discharges and the instantaneous peak discharges for the U.S. Geological Survey gaging station on Bay Creek near Pittsfield from 1961 to 1978. The watershed of this stream is adjacent to and approximately four times the size of the watershed of Pittsfield Lake.

These data are presented only to indicate variations in regional streamflows from 1961 to 1978 which may have affected the rate of sedimentation in

Pittsfield Lake from 1961 through 1979. These figures indicate relatively high streamflows and five record or near record streamflows during the period 1961 to 1974 compared with the 1975 to 1978 flows. Similar higher peak flows were probably present in the Blue Creek watershed in the same period. These higher peak flows before the 1974 survey could have resulted in greatly increased sediment discharges.

It is also possible that improved watershed management led to reductions in sediment runoff and in the sediment load delivered to the lake; however, a lack of background information on sediment load and water flows from the watershed makes a definitive analysis of the decrease in sedimentation rate very difficult. A joint Illinois State Water Survey - Illinois Environmental Protection Agency study has recently been conducted on the effects of watershed management practices on sediment runoff in the Blue Creek watershed. Data from this study may be useful in an analysis of the decreasing sedimentation rate in this watershed.

Paradise Lake and Lake Mattoon

Paradise Lake and Lake Mattoon serve as the water supply reservoirs from the City of Mattoon, Illinois. As shown in Figure 1, Lake Paradise is located on a subwatershed of Lake Mattoon. This subwatershed consists of about 25 percent of the total watershed.

The Paradise Lake and Lake Mattoon sedimentation field surveys were completed in 1979 and 1980, respectively, by the Illinois Department of Transportation, Division of Water Resources. The results of the Water Survey's sedimentation analyses are presented in Tables 3 and 4.

The sedimentation rates of 0.51 percent per year for Paradise Lake and 0.52 percent per year for Lake Mattoon are very close to the average sedimentation rates for other Illinois reservoirs as determined in the State Water Survey lake sedimentation program. However, when the results of the two surveys are compared more closely, it is seen that the sedimentation rate at Lake Mattoon is higher than would be expected if a direct extrapolation were made from the Paradise Lake results.

In general, it is expected that the sedimentation rates from similar watersheds are inversely related to the capacity per square mile of drainage area (C/W ratio; see Tables 3 and 4). If the Lake Mattoon watershed were exactly similar to the Paradise Lake watershed, the sedimentation rate for Lake Mattoon would be expected to be approximately (113/235) x 0.51 = 0.25%. However, the sedimentation rate calculated for Lake Mattoon is approximately double this value. There is obviously some major dissimilarity in the two watersheds.

The only obvious difference in the two watersheds is their geologic histories. The surficial geology of the Paradise Lake watershed is primarily morainal deposits from the Wisconsinan glacier while the geology of the

southern half of the Lake Mattoon watershed is primarily glacial outwash and loess deposits resulting from the Wisconsinan glacier. It is quite likely that these geological differences are the cause of the unexpectedly high sedimentation rate in Lake Mattoon.

This difference in the geological history of the watersheds is also reflected in the sediment yields in tons per acre of 0.80 for Paradise Lake and 1.57 for Lake Mattoon, as shown in Tables 3 and 4.

Lake Decatur

Lake Decatur, the water supply source for the city of Decatur, Illinois, has been considered a benchmark station for lake sedimentation in Illinois. Built in 1922, the lake has been surveyed in 1931, 1936, 1946, 1956, 1966, and 1983.

Preliminary studies of variations in the sedimentation rates of Lake Decatur indicate at least two potential correlations that might be made.

First, is the correlation between sedimentation and average annual inflow to Lake Decatur. Preliminary analysis has shown that periods of higher sedimentation rates correspond to periods of higher than average annual discharges.

Second, drawdown of the reservoir level during drought periods contributes to increased consolidation of the accumulated sediments. Consolidation results in reduced water volume losses from a given sediment mass. The process of consolidation would have been most important during the 1946 to 1956 period which was strongly influenced by the drought of the early 1950's.

The combined effects of runoff variability and consolidation can be seen in Figure 2. In this figure, chart A shows sedimentation rates for the 1936 through 1966 surveys by average volume accumulation, while chart B shows the same results in tons of accumulation per acre of watershed.

Climatic records indicate that the periods of 1922-1936 and 1936-1946 were much wetter than the periods 1946-1956 and 1956-1966. The result is significantly lower sedimentation rates during the latter two periods due to reduced water runoff. The influence of the prolonged drought of the early 1950's is seen in the 1956 results which show a relatively low volume loss for a rate of sediment input approximately equal to the 1966 rate.

Conclusion

Analysis of the many possible factors involved to determine their final effect on the sedimentation rate in a given reservoir is extremely difficult. On the basis of personal experience, the accuracy of empirically determined lake sedimentation rates is in the range of ±100%. However, use of these techniques with a little common sense and comparison with regionally

representative rates is the only means of estimating the sedimentation rate of a new reservoir.

After a reservoir has been in use for 5-10 years, a regular program of sedimentation surveys at 5-, 10-, or sometimes 20-year intervals is the only means of accurately planning for the long-term use of the reservoir.

Summary

The process of lake sedimentation can be described by a simplistic source, transport, sink model. As more basic factors are taken into account, the process becomes considerably more complex. Empirically determined sedimentation rates are limited in accuracy but can be used with caution for the design of new reservoirs. A regular program of lake sedimentation surveys is the best available means of accurately monitoring sedimentation in an existing lake.

Table 1. Summary of Sedimentation Data
Pittsfield Lake

Age		
	Years	
May 1961-Dec. 1974	13.5	
Dec. 1974-Aug. 1979	4.8	
May 1971-Aug. 1979	18.3	
Watershed	*Sq mi*	*Acres*
Total area	11.15	7136
Area excluding lake	10.78	6901
Reservoir		
Primary spillway elevation 596 ft above msl		
Surface area at spillway level	*Acres*	
1961	235	
1979	218	
Storage capacity at spillway level	*Acre-feet*	*Mil gal*
1961	3454	1125
1974	2878	938
1979	2773	904
Capacity per square mile of drainage area*	*Acre-feet*	
1961	310	
1974	258	
1979	249	
Sedimentation	*Acre-feet*	*Mil gal*
1961-1974	576	188
1974-1979	105	34
1961-1979	681	222

Average annual accumulation of sediment**

	Acre-feet from entire watershed
1961-1974	37.9
1974-1979	21.9
1961-1979	37.2
	Acre-feet per square mile
1961-1974	3.52
1974-1979	2.03
1961-1979	3.45
	Cubic feet per acre
1961-1974	239
1974-1979	138
1961-1979	235
	Tons per acre
1961-1974†	5.69
1974-1979†	3.28
1961-1979	5.59

Table 1. Summary of Sedimentation Data
Pittsfield Lake (Concluded)

Depletion of original storage	*Percent of original storage*	*Percent per year*
1961-1974	16.7	1.24
1974-1979	3.04	0.64
1961-1979	19.7	1.08

* Includes area of lake
** Excludes area of lake
† Tonnages prorated by sediment volume

Table 2. U.S. Geological Survey Gaging Station 5512500 -
Bay Creek near Pittsfield, Illinois
Drainage Area = 39.6 sq mi

Year	*Average annual discharge (cfs)*	*Instanteous peak discharge (cfs)*
1961	22.6	10,000*
1962	35.1	6,840
1963	16.1	6,150
1964	13.5	8,100
1965	37.1	12,600*
1966	34.7	12,200
1967	27.2	10,900
1968	25.5	5,000
1969	40.2	5,020
1970	84.6	11,300
1971	18.2	1,000
1972	14.4	1,830
1973	40.5	12,200
1974	47.8	6,450
1975	37.0	2,260
1976	14.4	2,400
1977	14.8	9,260
1978	32.2	7,290

* Flow Record

Table 3. Summary of Sedimentation Data for Paradise Lake

Age		
1908-1931	Years	
	23	
1931-1979	48	
1908-1979	71	
Watershed	Sq mi	Acres
Total area	18.1	11585
Area excluding lake	17.8	11389
Reservoir		
Primary spillway elevation 684 ft above msl		
Surface area at spillway level	Acres	
1931	196	
1979	166	
Storage capacity at spillway level	Acre-feet	Mil gal
1908	2042	665
1931*	1905	621
1979	1407	458
Capacity per square mile of drainage area**	Acre-feet	
1908	113	
1931	105	
1979	78	
Sedimentation	Acre-feet	Mil gal
1908-1979	635	207
1931-1979	498	162
Average annual accumulation (1931-1979)+		
From entire watershed	10.4 acre-feet	
Per square mile	0.58 acre-feet	
Per acre	39.7 cubic feet	
Tons per acre	0.80 tons	
Loss of capacity		
Total (1908-1979)	31.1%	
1931-1979	24.4%	
Per year (1931-1979)	0.51% per year	

* Adjusted for sedimentation, 1908-1931
** Includes area of lake
\+ Excludes area of lake

Table 4. Summary of Sedimentation Data for Lake Mattoon

Age	Years	
Built June 1958		
Surveyed May 1980	22	
Watershed	Sq mi	Acres
Total area	56.0	35,840
Area excluding lake	54.4	34,812
Paradise Lake Watershed	18.1	11,585
Reservoir		
Surface area at spillway level	Sq mi	Acres
	1.61	1028
Storage capacity at spillway level	Acre-feet	Mil gal
1958	13,160	4288
1980	11,660	3799
Capacity per square mile of drainage area**	Acre-feet	
1958	235	
1980	208	
Sedimentation	Acre-feet	
1958-1980	1505	
Average annual accumulation of sediment**		
	Acre-feet from entire watershed	
1958-1980	68.4	
	Acre-feet per square mile	
1958-1980	1.26	
	Cubic feet per acre	
1958-1980	85.6	
	Tons per acre	
1958-1980	1.57	
Depletion of original storage	Percent of original storage	Percent per year
1958-1980	11.4	0.52

* Includes area of lake
** Excludes area of lake

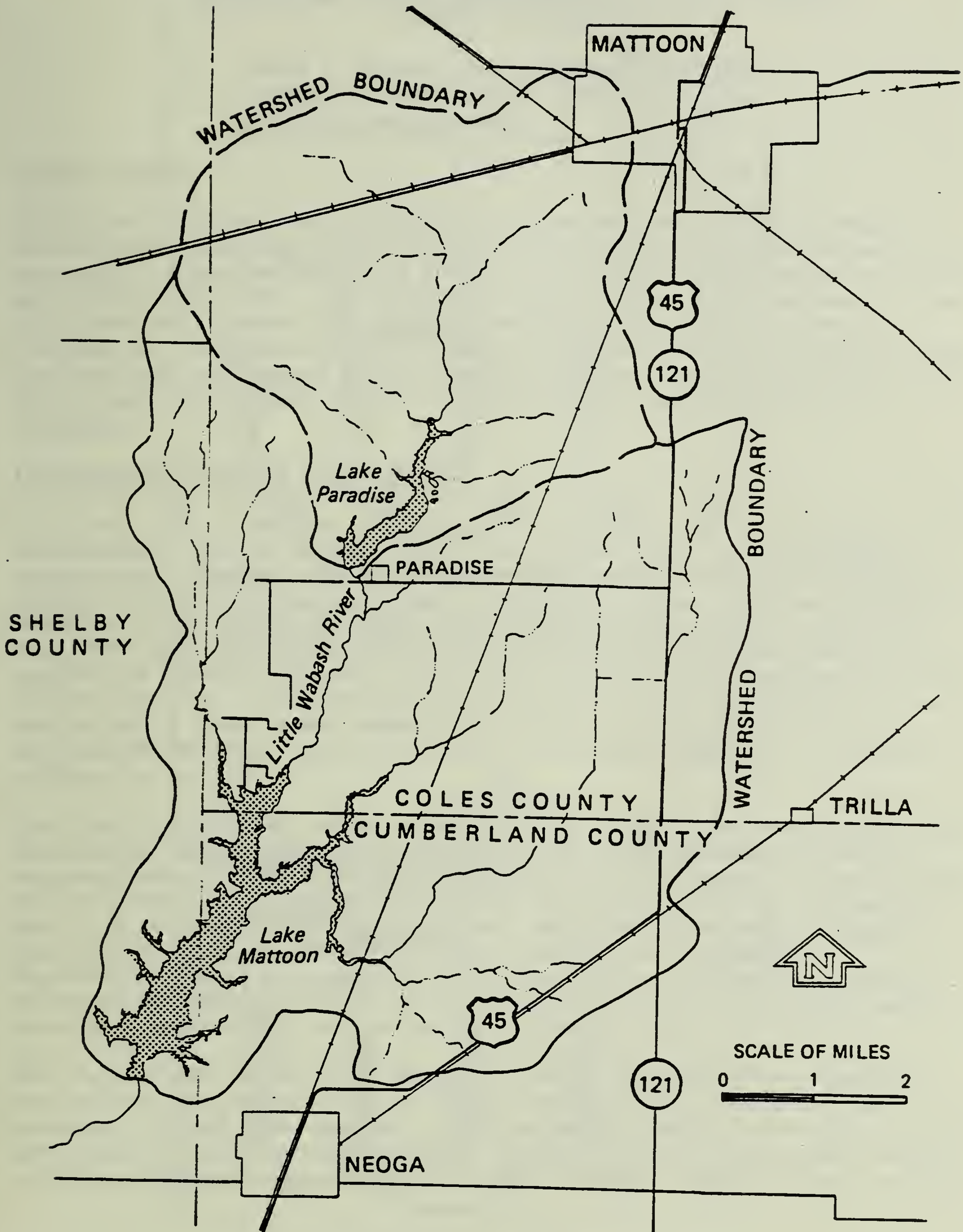

Figure 1. Watershed and location map of Paradise Lake and Lake Mattoon

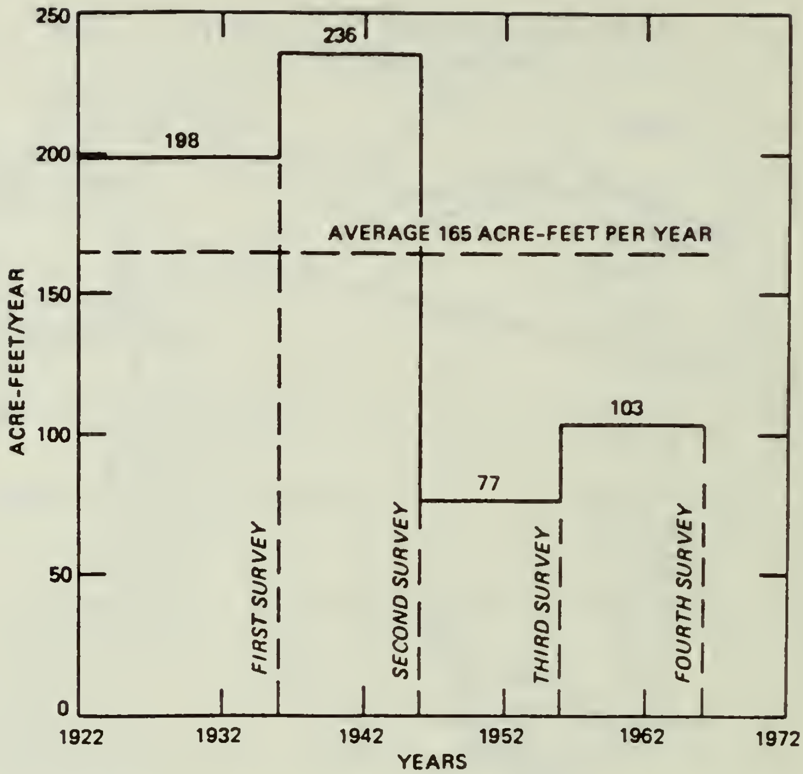

Chart A. Average Annual Sediment Accumulation by Volume, Lake Decatur

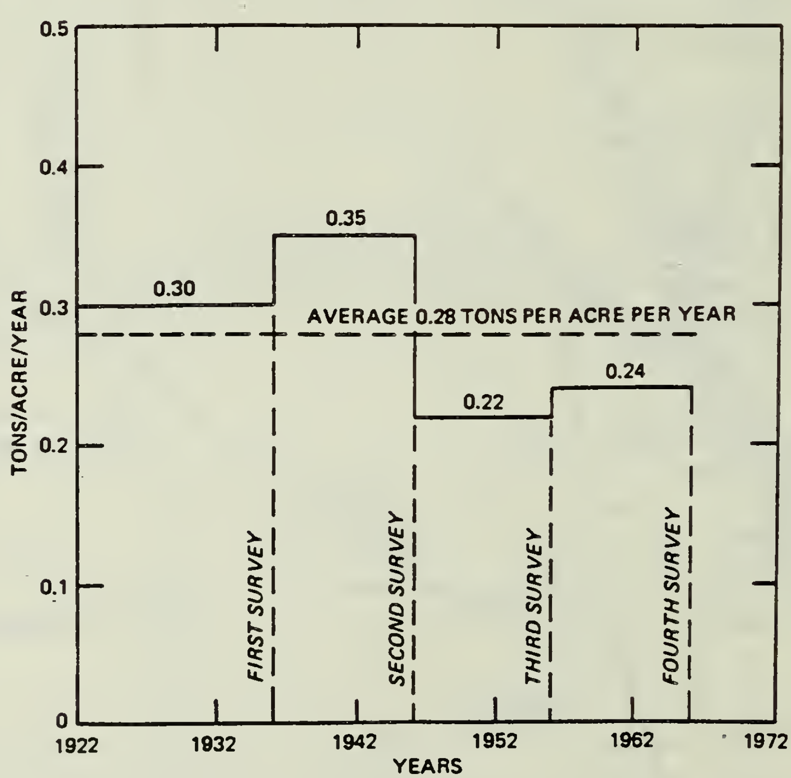

Chart B. Average Annual Sediment Accumulation by Weight, Lake Decatur

Figure 2. Variations of Sedimentation Rates in Lake Decatur

LAKE MONITORING FOR EVALUATING WATER QUALITY IMPACTS OF AGRICULTURAL RUNOFF AND SUPPORTING NON-POINT SOURCE CONTROL INITIATIVES

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Introduction

Lakes provide a good monitoring point for documenting off-site damages of agricultural runoff and evaluating the effectiveness of pollution control strategies, since they serve as traps or collection points for materials such as sediment, nutrients, and contaminants generated in their drainage basins. This paper will discuss lake quality/watershed relationships, how the Illinois Environmental Protection Agency (IEPA) measures lake quality through its Volunteer and Ambient Lake Monitoring Programs, and how lake monitoring data is used to document impacts of agricultural runoff and evaluate programs.

Lake Quality/Watershed Relationships

Lake quality is a function of the quality of runoff from the watershed. This is especially true in Illinois where most of the lakes are artificially constructed in fertile floodplains draining croplands, and are relatively shallow, short retention impoundments receiving frequent inflows of watershed runoff. Recent studies (Sefton, 1978; Boland, et. al., 1979; and Sefton, et. al., 1980) have shown that those Illinois lakes exhibiting the best water quality are generally deeper, with watershed area to lake surface area ratios of less than 10:1, large capacity/inflow ratios, and retention times of one year or more. These lakes generally receive less frequent inflows of nutrient and sediment laden water from the watershed and do not fill with sediment as rapidly.

Lake Sara in Effingham County is an example of a lake with morphological and hydrological characteristics conducive to good water quality. It has a watershed area to lake surface area ration of 10:1, an average retention time of 2.06 years, and an estimated capacity loss of less than 0.5 percent per year. It currently ranks among the best one-third to one-half of lakes in the state in water quality, but requires protection from further degradation. It is at a critical point where failure to control inputs of nutrients and sediment will result in continued rapid deterioration, while watershed controls will help maintain its good quality.

Lake Taylorville in Christian County, on the other hand, is an example of a lake with morphological and hydrological characteristics which are not conducive to good water quality. Lake Taylorville has a watershed to surface area ratio of 73:1, an average annual retention time of 0.226 years, and an annual capacity loss exceeding one percent per year. You can vividly see the

effects of agricultural runoff on this lake, as it receives frequent inflows of nutrient and sediment laden water and is very shallow.

Lake Monitoring

The IEPA has two programs to monitor the water quality of lakes in the state, the Ambient Lake Monitoring Program and the Volunteer Lake Monitoring Program. In the Ambient Program, agency personnel sample the lake water and sediment for various physiochemical parameters, such as dissolved oxygen, temperature, suspended solids, turbidity, nutrients, and algae. The Volunteer Program, on the other hand, uses citizens to gather valuable lake quality information. This paper will concentrate on Volunteer Monitoring, since it is a means of obtaining frequent data to document impacts and evaluate effectiveness at minimal cost to the volunteer. The ambient data is used to supplement the volunteer data.

Volunteer Lake Monitoring Program Methods

The Volunteer Lake Monitoring Program (VLMP) has proven an outstanding success for the IEPA. The program was initiated in 1981 to gather additional information about the lakes of Illinois and to respond to public interest and concerns about lake quality and lake management. The program encourages local involvement to solve local problems.

In 1981, 141 volunteers participated in monitoring 87 lakes, while in 1983, 255 volunteers registered to monitor 160 lakes. This represents an 84 percent increase in lakes and a 71 percent increase in volunteers since 1981. Over two-thirds of the volunteers who started in 1981 continue to be active in the program. Public Water Supply operators, Soil and Water Conservation District personnel, and Illinois Department of Conservation state park site personnel are well represented among the volunteers, as are lake association members, lake residents, sportspersons, and interested citizens.

The sampling instrument used in the volunteer monitoring is called a Secchi disc (Fig. 2). The Secchi disc is a scientific tool for measuring the transparency or clarity of the water. Attached to it is a calibrated rope marked off in feet and inches. A reading is taken by lowering the disc into the water until the white quadrants on the disc are no longer visible, then noting the depth on the rope. The disc is then lowered further and brought back up until it reappears. The Secchi disc depth is the average of these two readings. The deeper the Secchi reading, the clearer the water, while the shallower the reading, the more turbid the water (i.e., the more materials such as sediment and algae there are suspended in the water which interfere with light penetration).

In the VLMP, citizens select the lake they wish to monitor from among Illinois' 2,900 public/private lakes six acres or more in surface area. The volunteer's commitment includes attending a mandatory training session at the

lake of their choice, providing their own boating equipment, and collecting Secchi disc and field observations data consistently throughout the monitoring season at designated sites in their lake. The volunteers are loaned a Secchi disc and calibrated braided nylon rope. A fact sheet is provided describing the program. Detailed instructions on measuring Secchi transparency and total depth, making field observations, and completing data forms are included. A lake map showing the locations of three or more sampling sites designated by the IEPA is also provided. The volunteers also complete a three page lake assessment survey that provides information on lake morphology, uses, water quality conditions, shoreline and watershed conditions, potential pollution sources and current lake management practices.

The volunteers are expected to take Secchi readings and make field observations at three more lake sites twice a month (at approximately two week intervals) from May through October. More frequent sampling is suggested for those wishing to define watershed/lake quality relationships or assess the effectiveness of lake and watershed management practices. Samples taken after each major rainfall event help document the effect of agricultural runoff on lake quality (Fig. 3). Samples taken immediately before and 2-5 days after implementation of lake management practices (such as chemical treatment for algae or weeds) also help assess these practices (Fig. 4).

The volunteer fills out a form reporting the Secchi disc transparency readings and a two page field observations form for each site. Field observations include water color; amount of sediment, algae, and weeds; weather conditions; water levels; recreational uses; and lake management. These field observations (particularly information on water color and previous rainfall) are essential for interpretation of the volunteer's Secchi readings.

The Agency role is to: recruit and train volunteers, provide the Secchi disc and calibrated rope, identify sites on each lake, provide reporting forms and postage paid return envelopes, manage the data, and prepare reports.

An annual report, "Volunteer Lake Monitoring", is prepared which summarized the methods used and the results of the program (Sefton and Little, 1982; Little and Sefton, 1983). The report also contains a primer to provide the non-technical person with a basic understanding of Illinois lakes, factors affecting their water quality, and actions that can be taken to protect and enhance them. Data summaries are prepared for each lake and individual reports written as resources permit. Eighty-seven individual lake reports, which present and analyze the data for each lake and provide general recommendations regarding lake monitoring and management, were written in 1982 (IEPA, 1982). The reports provide direct feedback and a sense of accomplishment to the volunteers.

Newsletters are mailed to the volunteers monthly from June through September. They contain important reminders regarding the program, transmit publications or other informative materials, and contain a question/answer section concerning lake conditions, lake monitoring, and lake management techniques.

At the end of each monitoring season, all volunteers are sent thank you letters for their participation in the program. The volunteers who provided data for six or more sampling periods (total of 12 sampling periods in a season) are sent Certificates of Appreciation signed by the Agency Director.

Pollution complaint forms are sent to all volunteers who indicate on their field observation form that pollution problems are occurring in their lake. These complaints are then investigated by IEPA Field Operations Section staff, and a site visit made if necessary.

Lake watershed tours are arranged and conducted for volunteers in various regions of the state by Association of Illinois Soil and Water Conservation Districts staff, in cooperation with Soil Conservation Service, local Soil and Water Conservation Districts, and IEPA staff. The purpose of these tours is to acquaint volunteers with the impact that land use in a lake watershed may have on lake quality. The tours include a discussion of the erosion and sedimentation process, watershed sources of sediment and nutrients, land uses favorable and unfavorable to water quality, and land treatment to control watershed runoff.

VLMP Results

The IEPA is pleased with the success of the Volunteer Lake Monitoring Program, both in terms of the useful data collected and the important service provided to the citizens of Illinois.

Useful Data

Spatial, seasonal, and long-term trends in Secchi disc transparency, together with field observations and lake assessment information, are used to identify problems and causes affecting water quality and to evaluate and implement alternative protection/improvement strategies. Volunteer data are used to:

1. assess the basic lake character and possible pollutant sources;

2. identify prevailing conditions in different parts of the lake so as to pinpoint in-lake problems and possible solutions;

3. estimate the dissolved oxygen resources of the lake, which affect the ability of the lake to support a sport fishery, public water supply, or recreational activities;

4. document water quality impacts of non-point source pollution in order to support applications for USDA assistance program in the watershed, guide the implementation of agricultural resource management systems to critical areas, and evaluate subsequent effectiveness (see Fig. 3 and Sefton and Little, 1982b and 1982c);

5. guide lake management decision-making (e.g. determine proper timing and application rates of copper sulfate for algal control; determine public water supply withdrawal depths for improved water quality);

6. establish an historical data base for the lake, which includes morphological data; information on water quality conditions and problems; lake, watershed, and shoreline uses; potential pollution sources, and lake management undertaken; in addition to transparency, field observations, and total depth data collected under the VLMP. Without this historic record, it is almost impossible to document changes that have occurred or predict the effects of lake restoration or potential pollutant sources. In many cases, the volunteer data is the only monitoring data. It is almost always the most current data available;

7. compare with data from other lakes in the state, in order to target public and private resources for lake protection and management. In Figure 5, for example, the lakes are categorized by average Secchi disc transparency and plotted on a state map. This map show the area of the state with greatest problems with sediment and/or nutrients, and has been used by state and federal agencies to target sediment control programs in these areas. The lakes are ranked by are Secchi transparency in Figure 6. This data has also been used by Soil and Water Conservation Districts to identify the lake watershed most in need of soil conservation measures, and by the IEPA to prioritize projects for Clean Lakes funding and other assistance programs. Cooperative efforts fostered by the VLMP have also helped in implementing lake protection/restoration projects.

<u>Service Function</u>

The Volunteer Lake Monitoring Program provides an excellent opportunity to work with citizens concerned with lakes and to foster cooperation and develop local support for environmental programs.

This was vividly demonstrated at Lake Kinkaid in Jackson County and Lake Sara in Effingham County, where special volunteer monitoring is being performed to help document the effects of agricultural runoff on water quality, facilitate watershed management projects, and evaluate their effectiveness. These projects are excellent examples of Soil and Water Conservation District involvement and how the program has fostered interagency cooperation to accomplish soil and water conservation goals. Similar monitoring programs are being facilitated by the DeKalb SWCD for Lake Shabbona, the Whiteside SWCD for Lake Carlton, and the Fayette SWCD for Lake Vandalia.

At Lake Kinkaid, a cooperative monitoring effort involving the Jackson County Soil and Water Conservation District, the Kinkaid-Reed's Creek Conservancy District, the lake's Public Water Supply operator, the Soil Conservation Service, and the IEPA helped establish its watershed as the number one soil and water conservation priority in the state. The volunteer data helped document the effects of agricultural runoff from the watershed on lake quality (Fig. 3) and guide the implementation of soil conservation measures to critical areas of the watershed (Sefton and Little, 1982b). As a result, about $35,000 of 1983 Jobs Bill funds were used for recreational development of Lake Kinkaid, and planning authorization for a P.L. 566 watershed project was received in August 1983. The Lake Kinkaid watershed is the next P.L. 566 land treatment project scheduled for funding in Illinois, due in part to the data, interest, and cooperation generated by the VLMP (Hendrickson and Fitzgerald, 1983).

Similarly, at Lake Sara, the volunteer monitoring program helped establish a working relationship between the Effingham Soil and Water Conservation District, the lake owner (Effingham Water Authority), and the City of Effingham (which uses the lake as an alternate public water supply). The Effingham Soil and Water Conservation District has implemented a special watershed project based on the interest in protecting Lake Sara. The volunteer monitoring will also help evaluate the effectiveness of this project (Hendrickson and Fitzgerald, 1983).

VLMP Conclusions

1. The Volunteer Lake Monitoring Program enlists and develops local "grass roots" support for environmental programs and fosters cooperation among citizens, agencies, and various units of government.

2. The VLMP increases citizens' knowledge and awareness of the factors that affect lake quality and promotes ecologically sound lake protection/management programs.

3. The VLMP is a self help program which promotes local self reliance and implementation through local resources.

4. The VLMP targets public and private resources for lake protection and improvement.

5. VLMP data documents water quality impacts of point and non-point source pollution.

6. The VLMP provides an historic data baseline for documenting future changes and evaluating pollution control programs.

7. VLMP data supports lake management decision making.

8. The VLMP provides the framework for a technical assistance program for lakes.

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FIGURE 1

Location of Lakes in the Illinois Environmental Protection Agency's 1983 Volunteer Lake Monitoring Program

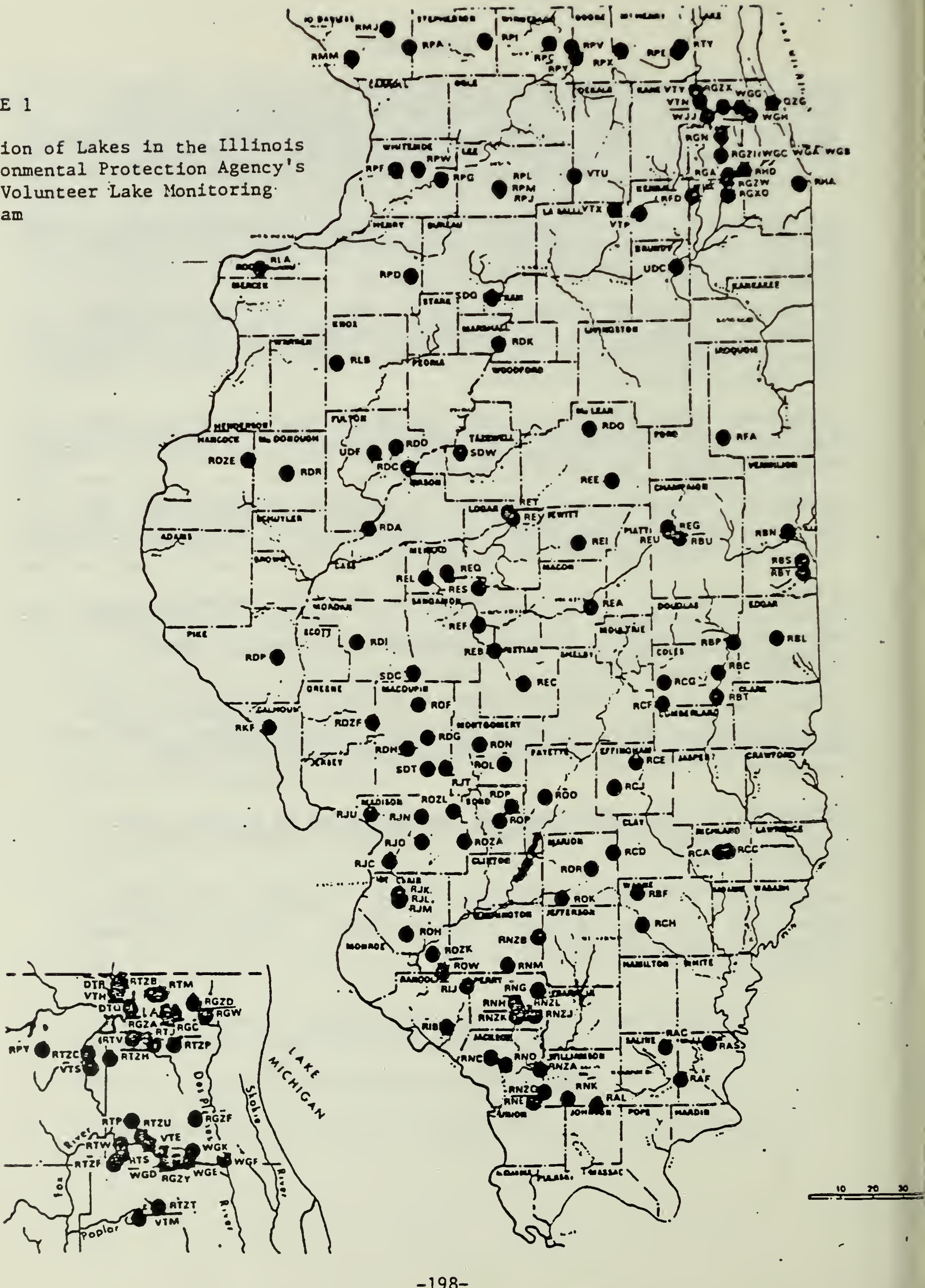

FIGURE 2

Measuring water clarity or transparency with a Secchi disc.

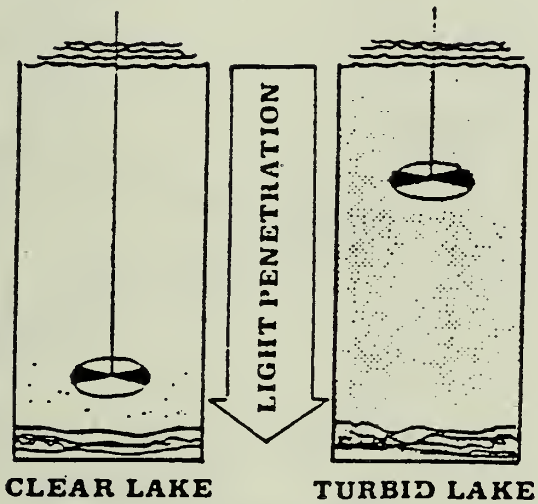

FIGURE 3

The effects of rainfall events and resultant watershed runoff on the Secchi disc transparency of Lake Kinkaid, Jackson County, Illinois. (IEPA Volunteer Lake Monitoring Program, 1982)

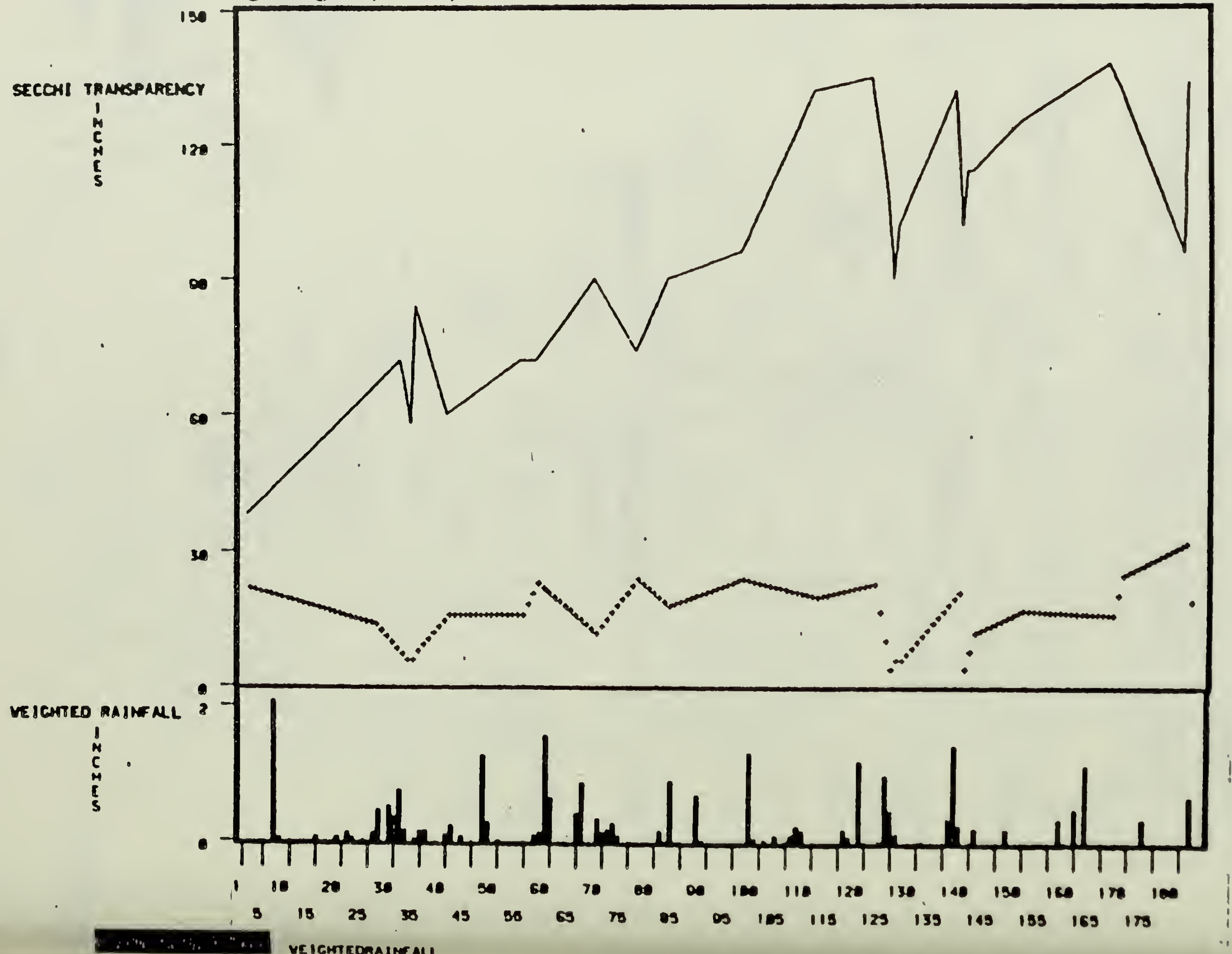

FIGURE 4

Impacts of chemical treatments of macrophytes and algae on Secchi disc transparency in Lake Barrington, Lake County, Illinois. (IEPA Volunteer Lake Monitoring Program)

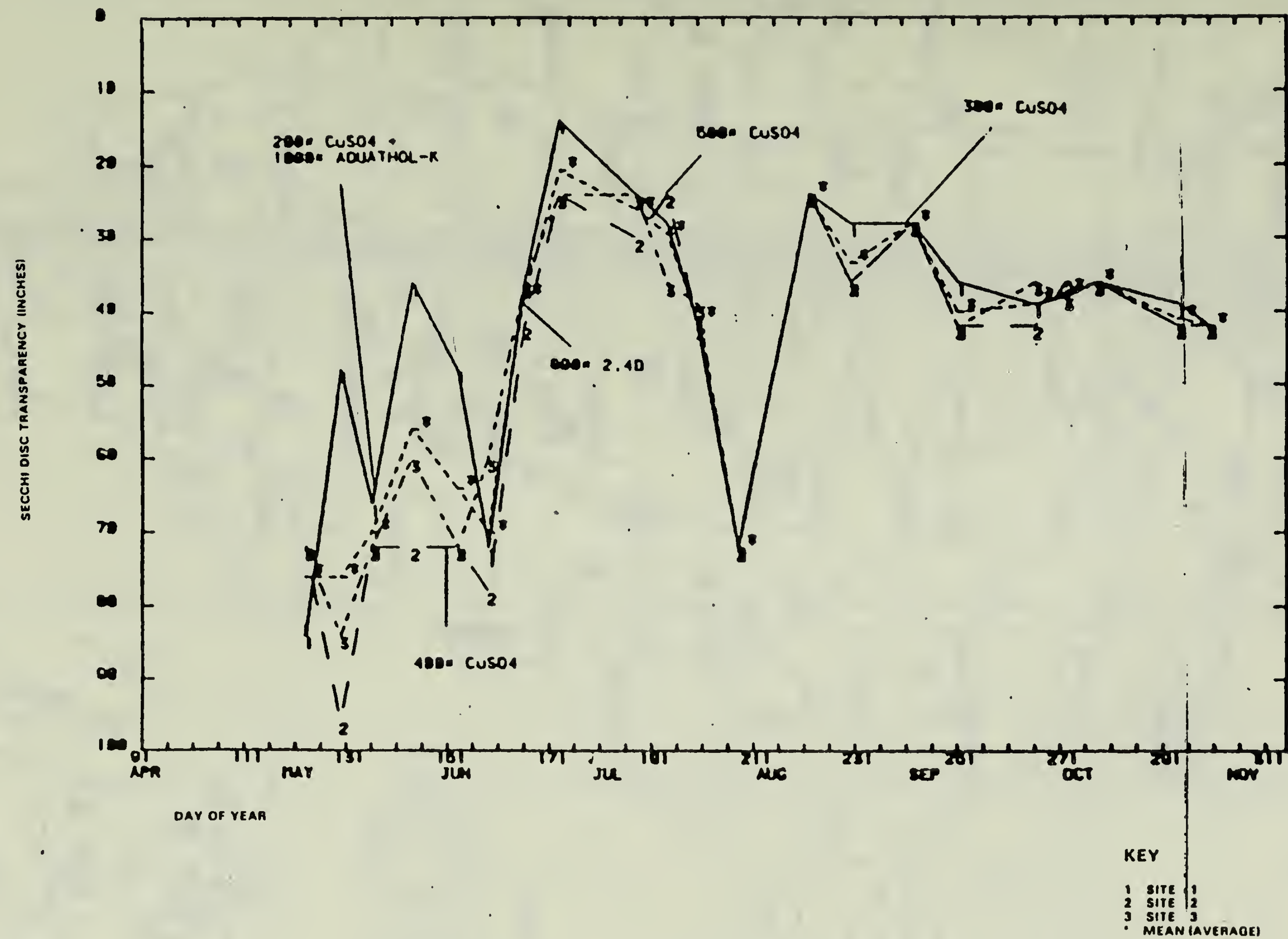

FIGURE 5

Secchi disc transparency data can help target resources to areas in the state with the greatest sediment and/or nutrient problems (IEPA Volunteer Lake Monitoring Program, 1982)

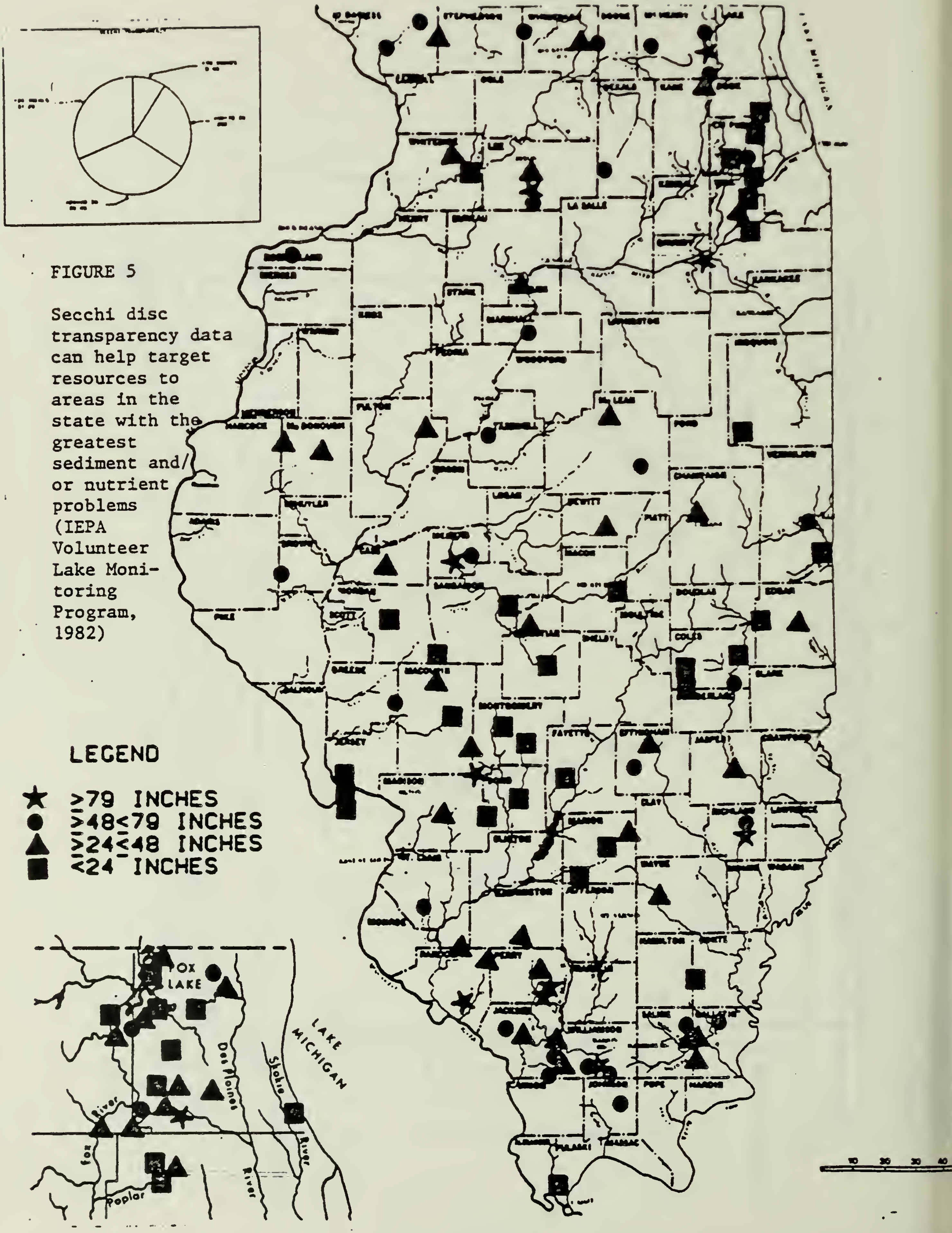

FIGURE 6

Ranking of lakes by average Secchi disc transparency (IEPA Volunteer Lake Monitoring Program, 1982)

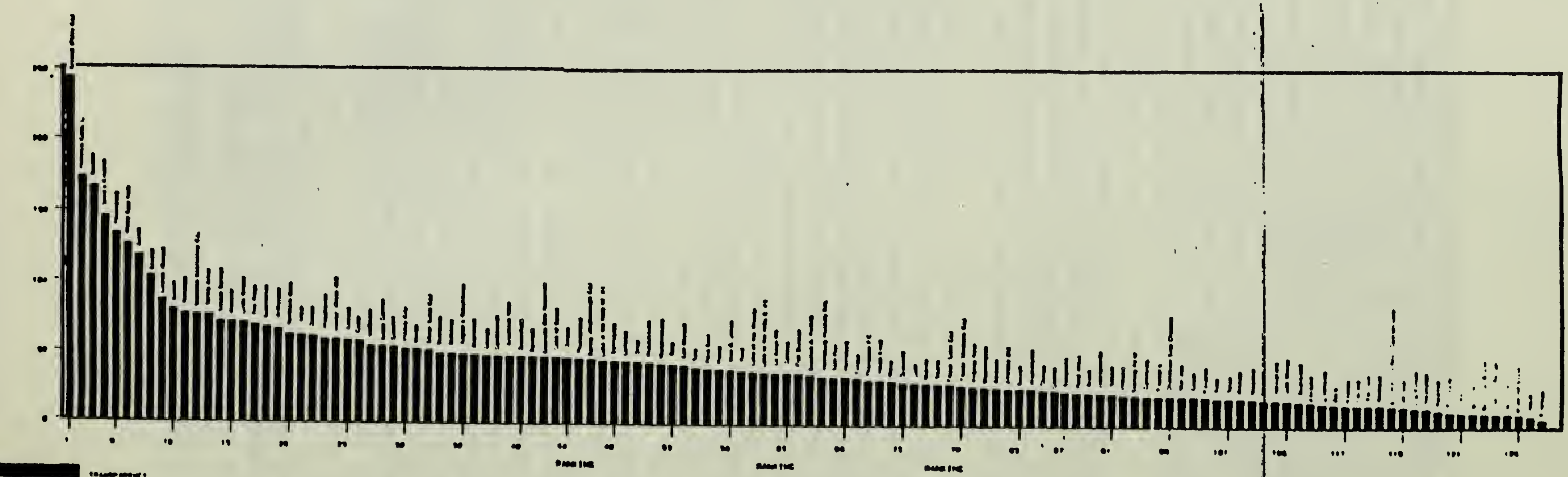

FIGURE 1. Ranking of 128 lakes by average Secchi transparency (inches), Illinois EPA Volunteer Monitoring Program, 1982.

WHO SHOULD PAY AND HOW MUCH?

Wesley D. Seitz, Head
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At this point you have invested nearly two days learning all about soil conservation and water quality. You have heard legislators, the Governor, the Director of the Department of Agriculture, faculty members, industry group representatives, and others address topics ranging over the historical, public policy, technical, ecological, computational, and socioeconomic aspects of the soil erosion problem. It appears that the conference organizers decided that, when all of these topics had been covered, it was time to get to the bottom line: who should pay for soil conservation and water quality efforts? I am delighted to have the opportunity to address this question, not because I'm able to give you definitive answers, but because I believe I have a way of looking at the question that you will find interesting and perhaps enlightening.

What I plan to do is share with you my perspectives on questions of equity or fairness and indicate how these concepts bear on who should pay for soil conservation efforts. I will suggest that there are several different ways of addressing the question. The answer you get depends upon your perspective, your value judgments. There is no objective way of determining the correct or the incorrect perspective or value judgment. The question can only be resolved in the public arena. While we may on occasion be frustrated with the answer generated, my guess is that we will all agree that this is by far the best approach available to us. It is up to us to make the system work as well as possible.

I want to caution you that I will be using some examples that are fairly extreme in nature. This is necessary to help you to understand the differences among the criteria and their implications. We all recognize that in general such questions are resolved through a process of compromise which generates outcomes that are in shades of gray. None of the participants are able to get everything they want.

Before I begin an analysis of who should pay, allow me to give you my characterization of the problem. For my purposes here, it is adequate for us to assume there is a reasonable amount of cropland in the state of Illinois, or the nation, that can be farmed in any reasonable fashion without excessive soil loss. On the other hand, some land in the state currently being used for crop production would need to be converted to other uses to attain T limits because economically viable combination of crop production and conservation techniques just do not exist to do the job. Still other lands can be used for crop production, but the crop rotation selected, the tillage practice used, and the conservation practice applied will determine whether the level of soil loss is above or below accepted levels. If appropriate

practices are not used, excessive loss will occur on millions of acres of this type of land in Illinois and the United States. The evidence clearly indicates that, if a farm operator determines how to farm on the basis of good business management practices, that is, maximize income over a reasonable period of time, in some cases excessive soil loss will occur. The point is that in some cases conservation pays for the farm operator, and in other cases it does not. In addition to the on-farm erosion damages, reductions in yields or increases in costs, there are off-site damages such as ~~sediment deposits in roadside ditches, drainage channel, canals,~~ waterways, and reservoirs, as well as a reduction in the quality of wildlife habitat, reduction in recreational use, or increased water treatment costs. In may cases these damages are more costly, per ton of soil eroded, than the on-farm damages. Of course, these costs are not paid by the farmer and therefore are not included in the farm-level profit and loss calculations made to select conservation practices.

These factors imply that the soil erosion problem will not go away of its own volition. Given today's technology, excessive soil erosion will occur, on some land, unless the public, acting through the federal, state, or local government, takes action. Government, therefore, has a legitimate role to play in addressing this problem so long as the cost of the program instituted is less than the damages it prevents, implying that the program if efficient.

I want you to know that I believe that economists have worn blinders when they looked at questions of equity. They, or we, generally define equity in terms of the distribution of income. If there is a wide gap between the rich and the poor, the income distribution in a society is said to be inequitable. Quite appropriately then, when evaluating any proposed policy change, economists address equity questions in terms of the impact on the rich, versus the impact on the poor. Policies that help the little guy rather than the rich folks are favored. Phrases such as "don't balance the budget on the backs of the poor" are fairly common and readily accepted. Stated alternatively, I doubt if anyone would argue that tax rates should be higher for poor folks than rich folks. While this concept is a legitimate and powerful dimension of the equity question, it is not the only dimension considered in the formulation of public policies that address societal problems. Equity, or fairness, is argued on grounds other than the distribution of income, and some of these grounds are just as credible in the policy-making process. Therefore, farmers will use the same criterion of earned rewards to argue that if the conservation activities undertaken for society's benefit result in extra costs or reduced income for the farmer, someone else should pay. Someone else, in this case, is either the general taxpayer or the individuals benefiting from the conservation activities. If the conservation activity is being applied to maintain the productivity of the soil for the benefit of future generations, the cost becomes a social responsibility, with payment from general tax revenues. If the erosion control is undertaken in order to provide clean water for recreational users, the earned rewards criterion will be used by farmers to argue that water users should pay for the conservation program in order to have the clean water they desire.

However, water users will use the same criterion to argue that farmers' activities are dirtying the water, and they should pay the piper for doing so. They may point out that, when corporate America was forced to come into compliance with stricter pollution laws, they were forced to bear most if not all of the costs of their compliance activity. In that case it was argued that pollution control is a legitimate business expense, a business expense that should be passed on to the consumers of the product being produced.

Water users may well argue that in this case controlling erosion and thereby sedimentation is also a legitimate business expense of the farming operation, an expense that should be built into the cost structure of agriculture and eventually into the cost of food.

It may be worth highlighting the impact of the application of this criterion on resource allocations. To the extent that the producers of goods and services, in this case farmers, pay the total costs of their productive activities, including costs such as soil conservation activities, consumers will need to recognize and deal with these and other arguments as we try to determine who should pay.

I assume that you have all heard Senator Long's line, "Don't tax you, don't tax me, tax the fellow behind the tree." Of course, we would all like to pay less taxes, and if we can find some way of justifying paying less taxes we argue the case strenuously. However, I assert that there are few in society who would make such an argument on the basis that they should not pay a "fair" share of the tax burden. Such an argument would not be credible.

A critical element, then, is the credibility of the basis for the argument put forward. The four dimensions of the equity question that I assert have general credibility are (1) earned rewards, (2) equality, (3) shared consequences, and (4) intertemporal equity. Arguments are made on each of these bases to support positions taken in the public policy arena.

Earned Rewards

Most people in society believe that you should get what you pay for, that you should earn what you get, that you should pay for what you use or the damages you do. This belief or set of values is deeply embedded in the American value system. There is no such thing as a free lunch — and this equity criterion says there shouldn't be!

The earned rewards criterion comes into play in several ways as we review alternative soil conservation policies. It implies that farmers should pay for any erosion control activity that generates benefits in the form of reduced costs of operation or increased production and thus higher income or increased sale value of land. If conservation will make my farm more profitable, you, as taxpayers, would probably not want to pay me for those conservation activities. Taxpayers tend to make more appropriate decisions as they choose among the goods and services available in the market. If a

consumer is choosing between two products with approximately equal costs of production but one is sold at a lower price because of government subsidies or because on off-site damage such as erosion is not reflected in the price, the consumer will tend to purchase the lower-priced product and thus encourage expansion of the industry receiving the government subsidy or causing the off-site damage.

Powerful images can be called to mind to support an argument that the farmer or the water user should pay for improvements in water quality. If one pictures a young boy with patched pants and a straw hat fishing in muddy water as a four-wheel drive tractor plows in the background, one is likely to react considerably differently than if one pictures a luxury yacht sailing by a farmer in patched clothes, who is constrained from producing profitable crops due to environmental regulations.

It appears that the concept of a watershed taxing district would provide a structure responsive to these arguments. Water users, be they municipal, industrial, or recreational, could be charged for the use of clean water. Farmers whose operations contribute sediment could also be taxed. The revenue collected could be used to operate a water treatment plant or to subsidize the adoption of conservation practices by farmers in the watershed. Adverse reaction to the creation of an additional taxing authority and concern about control are likely the major impediments to the adoption of such an approach.

Finally, the earned rewards criterion provides strong justification for the recent emphasis on targeting of soil conservation programs such as the ACP program of the ASCS. You will remember that a 1980 ASCS analysis reported that over 50 percent of payments were for practices applied on land with soil losses of 5 T/A, or less. This finding clearly indicated that tax revenues were not being spent in a manner which would generate the maximum possible impact. Incidentally, there are several possible ways of targeting such expenditures. Perhaps the highest erosion rate is the most obvious, but the thinnest soil, the highest damage rate, or the most benefit, are also possible, as is the criterion of the most benefit per dollar of expenditure. It is this final criterion which most appeals to the economist and is most consistent with the earned rewards criterion.

Equality

As noted, in public policy formulation, policies that help the rich get richer are less palatable than those that give the little guy a break. Some cynics, and perhaps some pragmatists, will argue that many policies do, in fact, help the rich. However, such policies are not justified on these grounds. It is much more likely that a policy change benefiting the "wealthy investor" will be justified on the basis that it will stimulate the economy and thereby generate jobs for the poor. The point is, in the policy formulation process, policies that tilt in favor of helping the less well off are favored as a result of our deference to the equality criterion. And how is this criterion felt in the soil erosion area?

To the extent that poorer farmers farm poorer land with higher levels of erosion, policies that provide subsidies for erosion control tend to be supported, while policies that constrain these farmers' options will be questioned. If a policy would reduce production, and thus profits, on the poorest farms and in so doing generate an increase in farm prices which would benefit the relatively richer farmers on good land, the policy will clearly be criticized on equality grounds. If the average income of farmers receiving subsidies for soil erosion control is lower than the average income of taxpayers, a conservation policy would be judged desirable under this criterion.

An effective targeting program would, on occasion, mean large payments to those farm operators who have serious erosion problems. Just as large payments made to large farmers under the price and income policies such as PIK are routinely questioned or even ridiculed in the press, based on the equality criterion, one must expect that large payments for soil conservation would also be criticized.

Similar income comparisons will be made between farmers and water users. To the extent that those who benefit from the program being proposed, be they farmers, consumers, or water users, are generally less wealthy than those who "pay the bill", the policy will be favorably assessed under this criterion.

Shared Consequences

This criterion is a powerful political reality, but one the economist tends to find less appealing. At the extreme, shared consequences implies that everyone should share in the benefits or the costs associated with the adoption of a new policy. It implies that everyone should bear a share of the cost of controlling erosion—taxpayers, consumers, farmers, water users, etc. For example, this argument was especially telling several years ago during the energy crisis. The federal government attempted to develop policies for allocating energy in that potential crisis situation, but found it was essentially impossible because of the in-fighting among regions to assure that the northeast, or midwest, or some other region was not unfairly burdened while another region of the country benefited.

For many years payments made under the ACP program were limited to a fairly small size and allocated among farmers on a first-come, first-served basis. All farmers in districts covering the nation were eligible under guidelines approved at the state and federal level. These procedures are clearly consistent with the shared consequences criterion, many small payments, widely distributed, available to any and all farmers. It is not surprising that, as noted earlier, this procedure resulted in more than half of the ACP cost-share funds being spend on land that was experiencing erosion of 5 T/A or less. I was quite interested to learn from a federal ASCS official that, as a result of the shift to a targeted program, only 7 percent of ACP funds are now spend on lands with less that 5T of erosion per acre. The shared consequences criterion is no longer the dominant force, the earned rewards

criterion with its emphasis on efficiency, and the intertemporal criterion I'll discuss next have taken on more importance.

However, as is generally the case, the change has not gone to the extreme of closing down SWCDs or eliminating ACP payments in low erosion areas in order to focus even more effort on those areas with high proportions of land needing treatment.

This criterion would also make it difficult to implement a soil erosion control program which would prohibit agricultural production on highly erosive land, especially if that land was concentrated in certain regions. There would be strong adverse reaction because of the negative impacts on the economy of that region. This same argument is the reason payments made under price and income support programs vary according to the profitability of agriculture in a given region, even though more land could be taken out of production with a uniform payment system. The uniform payment system would retire a large proportion of the land in certain areas while not retiring land in other areas. The consequences of such an approach would not be uniform over farmers, agribusinesses, or rural communities.

Taxpayers have, for years, shared in the cost of erosion control. With each new farm bill debate, the extent of that sharing is argued anew. Whether water users have shared consequences depends on perspective. The farmer on erosive land may argue that they have not shared in the cost of control and that they should share in that cost. Water users, on the other hand, would likely argue that they have been forced to tolerate sediment-laden water and that the farmers have not been forced to share adequately in the cost of preventing erosion.

One other group that has not to date been forced to share in the cost of erosion control is the foreign comer of U.S. agriculture. Given our emphasis on developing foreign markets, it is unlikely that we will move in this direction.

Intertemporal Equity

Rawls, in his book, A Theory of Justice[1], referred to a veil of ignorance. Suppose that every human being who has every lived or will ever live on earth were to decide on soil conservation policy (and all other policy) behind a veil of ignorance. Only after making these decisions, each person would learn his or her place in society. Soil conservation policy may be significantly different. This is analogous to asking me to cut the pie and telling me that I will get the last piece chosen. If we were to develop a soil conservation policy and then learn whether we were farmers on erosive or non-erosive soil, or if were were water users, or taxpayers, or consumers, or university researchers our approach to the problem might be quite different. But most important for this discussion, we would only then learn whether we would live our life in the past, present, or future. How much would we spend on soil erosion? How much would we spend on crop production research?

Using a more common way of expressing the point, we all want our children and grandchildren to be able to live "the good life", but just how much of our resources should we spend (or save) for the future? This concern for the future, the conservation ethic, has been at the heart of this debate for years. It is the most common way of expressing the fundamental imperative of a society to provide for generations yet unborn.

Perhaps it is sacrilegious, yes, the Bible, Genesis 1:26, does say that man has "dominion over the fish of the sea, and over the birds of the air, and over the cattle, and over all the earth", but stopping erosion now may not be the most efficient way to assure the well-being of future generations. For example, given that we have adequate soil resources to provide food and fiber in the short run, perhaps resources should be diverted from soil conservation programs to support research on new plant varieties or new techniques for conserving the soil or even producing crops in other mediums. Perhaps a perennial corn plant that fixed nitrogen could be developed if an ambitious research program were mounted for a reasonable period of years. Such a plant certainly would have the potential to revolutionize corn production and, at the same time, dramatically reduce erosion problems. Perhaps a leguminous plant could be developed for use as a ground cover in corn production. Other means of controlling water and light and nutrients may be found during this period of time, which would completely revolutionize agriculture as we know it.

This line of reasoning argues that it is most important to invest in the development of new technical knowledge and in the education of people. Doing so will give our progeny the best chance to deal with the problems they face. If we do a research job now, while we have temporary surpluses, perhaps we can reduce our dependence and theirs on soil. As a backstop, we might also expand the research on how to effectively reclaim damaged land and sediment-laden water resources.

Incidentally, not everyone will agree that this generation should sacrifice for future generations. Those who take this position argue that in the course of history living conditions have trended upward over time. If this trend can be expected to continue, it is reasonable to ask why this generation should sacrifice for the welfare of the next generation. Should our ancestors have sacrificed more so that we could live even better? A particularly crass individual might ask, "What have future generations done for me?"

Even if such a research program has a high probability of success, my biases do not allow me to argue we should neglect the erosion problem. I am not willing to "put all my eggs in that basket" and to risk the welfare of future generations. Because the amount of land is limited, plant production research will be needed simply to keep up with the population growth, even with erosion controlled. That may be challenge enough. However, the tough policy decision of the allocation of funds between these two, and all other alternatives remains.

Conclusion

We have identified four dimensions of the problem. Equality, earned rewards, shared consequences, and intertemporal equity can and will be brought to bear in any public policy decision process such as determining who should pay for soil conservation. If you agree with me that these are legitimate, credible criteria, that arguments based on these criteria will be accepted in Springfield or Washington, D.C. then what does this say to us as to who pays and how much? First, it says that this question will have many answers. These answers will depend upon the beliefs or value judgments of those involved in the decision process. There is no one correct answer. Secondly, this is the type of problem that can only be resolved through the political process. Here such arguments are tested, weighed, and balanced. Farmers, water users, taxpayers, and consumers will and should make their case as forcefully as they can. Frankly, I believe we in the business of doing research should be providing more information to decision makers on the alternatives available and their consequences. I suppose we all agree with Winston Churchill's observation that the democratic form of government is a horrible system to use in making decisions of this type, but that it is better than any other system available.

The democratic system is, at least ideally, open and fair to all. We all have a chance to make our opinions known as to who should pay and how much. We can write a letter, or join an interest group, vote for a candidate who shares our views, or even be a candidate for office. If the system is as good as we can make it and if we have made our input, we are obliged to accept the outcome, at least until we have our next chance to change it.

[1]Rawls, John, A Theory of Justice, The Belknap Press of Harvard University Press, Cambridge, Mass., 1971.

Q. (Dennis Barnard Macon SWCD Director) Have Soil and Water Conservation Districts been remiss in requesting county Farm Bureau help? How can we get a higher priority on soil conservation?

A. (Harold Steele, Illinois Farm Bureau) Our policy position on soil conservation as established by our farmer delegates is very clear. Our policy is to be a forward, working organization to enhance the soil conservation program for conservancy. One of my responsibilities has been to direct our policies with the daily operations of staff input.--These operations are directed at several areas. First in working with the farmers. Jon Scholl, for example, is responsible for working with farmers, groups, and soil and water conservation districts in the formulation of educational programs to use the soil loss formula to visually show the soil loss with different tillage methods and slopes.

The American Farm Bureau Federation also has a very clear and precise position on soil conservation and water quality and they work diligently with congressmen on these issues.

I will also be working with the Illinois delegates to bring forth the kind of direction that we work for for greater and carefully planned research on soil loss, tieing it to the economic return to the farmer.

For the other part of your question on whether soil and water conservation districts should work closely with the Farm Bureau, the answer is absolutely yes. We know that we individually respond if the wife says she will have lunch if you wash the window. In the same way if a county farm bureau board is face-to-face with the pressures of the county soil and water conservation district through a joint meeting, it brings an awareness and togetherness and peer pressure to bring about greater activity. The same kind of people are on both boards.

Q. (Steve Fest, Jo Daviess County farmer) Has I-LICA seen a reduction in soil conservation work in the last year or two?

A. (George Turner, President I-LICA) We have a reduction. We were hoping with the PIK program this year that it would be a good year for conservation work. Although in some parts of the state contractors have seen increases, in the southern part of Illinois we have seen a reduction. Cost sharing money is not there and farmers don't have the money themselves with the farm economy in the past couple years.

The farmer will not invest this money unless he can see a clear way to pay for it. They might say that soil conservation has been going on for years and maybe we can get to it next year if we get enough money for our crops.

END OF NOVEMBER 9 GENERAL SESSION QUESTIONS AND ANSWERS

NOVEMBER 10 GENERAL SESSION QUESTIONS AND ANSWERS

Q. (Ed Konigsmark, SCS District Conservationist·Pope-Hardin Counties) Has any of the $50,000 state appropriation for servicing erosion complaints been used?

A. (Gary Wood, Illinois Department of Agriculture) No, it has not been used yet. The soil and water conservation districts are presently developing their cost sharing schedule and those which have valid complaints can begin submitting requests. We need to emphasize that these funds can only be used for land on which a valid complaint has been filed.

Q. You told us what the soil loss was on land with complaints. What will it be after the plan is developed and carried out on the land with complaints?

A. (Gary Wood) Of the 11 or 12 that were out of compliance, so far only five schedules of compliance have been developed. To my knowledge only 2 or 3 have reduced soil loss to "T". In one case the field was converted to pasture. In others the tillage system was changed to meet the current standard. We are not far enough along in this first year of the process that everyone has developed a schedule of compliance.

Q. (Dick Thom, Illinois Department of Conservation) Does your soil loss productivity model account for yield improvements due to genetic improvements.

A. (Steve Probst, State Resource Conservationist, Soil Conservation Service) Yes, the yields on eroded soil are going up due to technology (including genetic improvements) and because farmers spend more money to use that technology.

As an example, let's look at nitrogen fertilizer. When we learned to produce cheap ammonia fertilizer, it was an improvement in technology. But the farmer must invest more to use that technology. It was cheaper to grow corn in 1930 than today. The results have been increased yield. If a farmer has eroded soil, his inputs are greater and his yields are less consistent. Hybrids are considered in our projections and they keep driving the line up. There will always be production differences though, between eroded and noneroded soil and we have seen this difference due to the drought this year.

Q. (Steve Fest, Jo Daviess County farmer) We recognize that technology improvements have covered up effects of erosion, and we also know that agricultural research budgets are being cut. Do you foresee that yield reductions on eroded soils will show up faster in the future?

A. (Steve Probst) If we would reduce the inputs, management, and capital investment, we would see that both production lines move downward and the spread between the uneroded soil and eroded soil becomes greater.

Current economics is driving those lines further apart and making the uneroded soil more valuable. If new technologies do not materialize and inputs remain level, the uneroded soil stays at about the same level but the eroded soil line drops off.

A. (Robert Walker, Cooperative Extension Service) You have also asked whether we will continue to have continued technology increases. Many people have questioned the limits of corn yield increases and potential for future increases with our past high rates of increases.

I assume in the future we will have a lower yield increase rate than the 2 - 2½% increase per year with corn. Even with a 1 to 1½% increase due to technology over 40 years, we should still be capable of growing 140 bushels of corn on a silt loam soil. We have advanced beyond that, but I don't believe the increases will be as great in the future.

Q. (Byron Kotter, Schuyler County SWCD) Is there data giving the relationship between field compaction and soil loss?

A. (Bill Moldenhauer, Agricultural Research Service) The data is very sparse. Logic tells us that compaction makes quite a difference. After four years of work, partly with Kent Mitchell on strip mine reclamation using rain simulation, this relationship shows up very well on reclaimed lands. I expect it shows up to a lesser degree with sloping agricultural soils. To best answer your question, there is very little data except on the extreme case of strip mine soils. Although compaction and crop production are being researched, very little has been done on soil loss. I think it is an area that needs to be investigated.

Q. (Lester Johnson, Resource Conservationist, Jo Daviess SWCD) Changes made a couple of years ago in the "C" (conservation practice) factor of the Universal Soil Loss Equation effectively reduced erosion statewide by 10 - 15%. Do you anticipate any other changes of this nature?

A. (Bill Moldenhauer) It is hard to answer, but we are looking into it. In Handbook 282, we had very little information on the "C" factor from surface residue. The erosion plots on which Handbook 282 were based had virtually no surface residue. When Wischmeier revised Handbook 282 into Handbook 537, there was still very little information so we went all through the corn belt reviewing and extrapolating available information into a reasonable "C" factor. Since then we have more data from Ames, Iowa and our group in Lafayette, Indiana which suggests quite low "C" factor values for surface residue. To have a good data base we need many years, many researchers and many locations. With only two locations, many people are skeptical and we will probably split the difference between Wischmeier's "C" factor values and those determined through the ARS Ames and Lafayette research.

Q. (Bob Walker, Cooperative Extension Service) There have been concerns expressed regarding soil compaction with no-till farming. Is there data to provide a guide on compaction?

A. (Bill Moldenhauer) One needs to define compaction. We also need to recognize that any soil will reach a certain bulk density in the year following tillage. Instead of a density of 0.8 or 0.9 it may reach 1.3 or 1.4 at the end of the year. Naturally with a no-till situation, it will approach this higher level. Another problem with no-till is that wheel track compaction is not corrected with freezing and thawing but can be through tillage. Many people

don't seem to realize this. Another factor, which I find amazing, is the effect of a legume which helps loosen the soil. Soybeans also loosen the soil to the point where it is very erodible but it is also easier to work with in no till.

The ARS has a little work going on throughout the country and we will be able to get a handle on it after awhile.

There is difficulty in separating what the soil would get to whether it had tractor traffic or not. An advantage with till-plant operations is that they can go into controlled traffic which is very helpful in reducing compaction. If you drive all over the field you can get up to 75% of the field tracked in a year and this happens a lot on plowed fields.

LUNCHEON NOVEMBER 10, 1983 QUESTIONS AND ANSWERS

Q. (Eldora Zimmerman, Winnegabo SWCD Chairman) It is difficult if not impossible for a farmer to charge more for his product to pay for installing conservation practices. Will the lost production resulting from erosion be charged to us or to the next generation?

A. (Wes Seitz) Yes, the costs will eventually be passed onto society. If only a small number are forced into installing the conservation practices, those farmers will have the most difficulty. My point is that the costs will eventually show up. The next generation will be affected when the production drop off occurs.

Q. (Steve Fest) Farm organizations are independent and often have diverse views. Do you think they can unite and work together like environmental groups?

A. (Wes Seitz) First, environmental groups are probably more diverse than farm groups. Second, generally farm groups work together, but one of our staff found that over 250 groups are trying to impact national farm policy. Farmers and farm groups will take different positions for very good reasons.

Q. Do you envision a national conservation check off program which would generate income for conservation?

A. (Wes Seitz) I doubt it because it would be a new tax and create a new administrative structure. Furthermore, it would not fairly allocate costs to the beneficiaries -- namely the international food purchasers. The so-called "fat lady in Stuttgart" would not pay any of this tax.

Q. Couldn't this type of tax be collected at the miller's level?

A. (Wes Seitz) Possibly, but regardless of where in the food supply system it is collected, the farmer will pay. I have suggested that this type of tax be collected by export farmers to enable international payment of the resource costs of an export grain economy.

Q. (John Ash, Iroquois County farmer) Do you envision state legislation to provide watershed type districts with taxing authority?

A. (Wes Seitz) Although it would be mechanically possible to draft enabling legislation, I doubt whether it would be passed because of resistance to any new taxing authorities. Also, residents of the watershed would need to approve the new taxing authority in a referendum and this is difficult when they would all incur greater property tax liability regardless of their potential benefits. Some watershed residents would probably receive more benefits than others.

COMMENT. (John Ash) In Iroquois County we recently voted on the formation of a river conservancy district. About 3/5 of the voters were opposed to it, but probably less than 2% knew what the conservancy district was about.

We need to continue informing and educating the public and we hope to try again. More information and education are needed.

COMMENT. (George Deverman, Menard County SWCD) In a referendum like that in Iroquois County, the people on high ground some distance from the water are likely to vote against it, but those near the water or ditches will support it.

COMMENT. (John Ash) The greatest opposition in our River Conservancy District proposal was from drainage board commissioners who apparently felt threatened by it.

COMMENT. (Harold Dodd) I want to reiterate the point that farm organizations are working together, but it is appropriate to have diversity and competition among farm organizations.

COMMENT. (Wes Seitz) Yes and if there was only one farm organization it would probably be fractionated with differing perspectives.

CONCLUSION. (Don Holt, Director Agricultural Experiment Station) Since either my father or I were involved with the Kendall County Soil and Water Conservation District from 1951 to 1963, I greatly appreciate the work of soil conservationists and the great contributions soil and water conservation district directors make.

I will close this conference by leaving one thought with you: Although there is a healthy diversity in opinion on certain conservation issues, all of us -- farmers, consumers, environmentalists, educators, conservationists, researchers -- are in the same boat and we must continue to work together as we have during the conference in maintaining our food supply and our environment.

FIRST DAY GENERAL SESSION QUESTIONS AND ANSWERS

Q. (Eldora Zimmerman, Winnebago County SWCD) In Winnebago County, our Soil and Water Conservation District has experienced the agony of county board funding decisions. We worked very hard to convince the county board to maintain some of our budget after they had completely removed it. Are any imaginative state funding programs on the horizon to reliably fund districts without having to rely on political whims?

A. (Jim Frank, Department of Agriculture) Winnebago County Soil and Water Conservation District had the highest county board funding level of any county in the state with about $31,000 and it was reduced to nothing in the initial county board budget. Since the state funding allocation is partially based on county board funding, it too would have dropped. Fortunately, the Winnebago District recovered from the anguish and got the budget partially reinstated.

The answer is hard work and there is no substitute for that. I will mention two things on the federal level that look promising: (1) I hope the USDA grants program to districts becomes a reality. Fifteen to $25 million nationally is being discussed and it would be granted to districts for technical staff. (2) The federal EPA Clean Water Amendments appear to have a 50/50 chance of including a grants program for nonpoint source pollution control. The funding would go from Federal EPA to the Illinois EPA and hopefully then to districts to hire technical staff.

These things on the horizon will help if they are passed, but we will never remove this type of program from the whims of politicians. They can jerk the programs out just as quickly as they put them in.

Therefore, it is imperative that county funding and city funding (such as from municipal water authorities) be viewed as a more important part of your program, so that you have more local control. As long as you are relying on tax dollars, however, you will be relying on the whims of some politician, whether federal, state, or local.

Q. (Hillard Morris, Effingham County SWCD Chairman) I believe that we will never get the immense soil and water conservation job done with general purpose revenue funding. Isn't it time to set up a special fund? Perhaps we could call it the Illinois Resources Protection Fund. The funding would need to be firmly established and I would like to see a 1/4 or 1/8 of 1% sales tax left on food. My philosophy is that those who eat the food and drink the water should help protect our resources and I believe that they would be willing to pay. A 1¢ sales tax converts into about $100 million per year.

Another idea is to put a tax on commodity trades. What amount could we realize from a nickel charge on each commodity trade?

Still another idea is to put federal oil surcharges into a Resource Protection Fund rather than the general fund.

Perhaps there should be a tax on alcohol which is produced from many Illinois bushels of corn.

Establishing this type of a fund can be done and society will support it. By having a special fund we will not have to compete with welfare and education for general purpose revenues.

A. (Larry Werries) There is a precedent in Missouri where $\frac{1}{4}$ of 1% tax on food (amounting to about $20 million per year) goes for natural resources including forestry, parks, and natural-resource areas.

(Hillard Morris) Soil and water conservation should be the main purpose of such a fund.

Q. (John Ash, Iroquois County farmer) Can Soil and Water Conservation Districts be given taxing authority? In Iroquois County, we recently tried to establish a conservancy district which would have had a corporate taxing power, but we were turned down in the referendum.

A. (Larry Werries) I will ask the people in this room whether that's the method to pay the bill. Are there any comments or questions on this?

COMMENT. (Ron Lawfer, Jo Daviess County Board) I have a comment regarding the "whims of local politicians." I am a member of the county board and reviewed the county budget yesterday. Get to know your county board member and make your whims known to him and support him. The amount in our budget for soil and water conservation is small compared to public health and road budgets. The whims of the politicians will go the way their constituents tell them.

LEGISLATIVE SESSION

Q. (A.G. Taylor, Illinois EPA) Do you as legislators perceive a unified "soil and water conservation family" approach by state and federal agencies or do you see diverse individual approaches by many agencies and organizations?

A. (Senator Joyce) During the past couple of years, there has been a tremendous improvement in unity in the agricultural community on conservation issues. Not only agriculture -- but now the League of Women Voters has testified on soil conservation. We are seeing broader support for soil conservation. We know that only about 1/100 of 1% of the state budget goes for soil conservation and to improve it you will need more than farmers and soil conservation people involved. You are going in the right direction.

A. (Representative Rea) In the past couple of years, we have seen a much closer working relationship at the state government level. We have seen the coordination and working together of various state agencies. I think this is of great value. For example, you see the Environmental Protection Agency, the Department of Conservation, the Department of Agriculture, and the Department of Transportation all working together now, which has not always been the case.

As a result, I have seen instances where the agencies have worked together to resolve problems. We have come a long way in the past several years of more cooperation, coordination and integration of state government programs and federal agencies are working much closer with us now too.

A. (Rich Carlson, Director Illinois EPA) Its a pleasure to hear from a legislator that the executive branch is working in a coordinated fashion.

Before I became director of the EPA, I was in the Governor's office working on environment, energy and natural resources. In the past four or five years, there has been a tremendous increase in the visibility of soil conservation issues and the ability of state government to organize around and address the various facets of soil conservation. I think the progress has been remarkable.

Q. (Steve Fest, Jo Daviess County farmer) Why has the public joined the farmer in support of soil conservation issues? What reasons are there for this increased support?

A. (Representative Rea) I think that one thing which has helped is the large number of public hearings throughout the state with excellent publicity and participation. It involves farmers and people from urban areas as well. For example, in the development of the State Water Plan, we conducted hearings in all regions of the state and local committees worked on the problems. There has been much more information and education and it has helped greatly. There must be a public awareness program and there must be input into the decision making process from all groups. When this happens, progress results.

NOVEMBER 10 SECOND SESSION QUESTIONS AND ANSWERS

BOB CLARKE'S PRESENTATION

Q. (Bob Smith, SCS) How many hog lots are in the Blue Creek watershed?

A. Quite a few and the number of hogs fluctuates during the year.

Q. (Harold Ault, Fulton County Board) What can be done about a person bulldozing down forest near the mouth of the Spoon River?

A. Unless there is direct damage to a waterway, there is no law to keep a farmer from bulldozing woodland.

BART ELEVELD'S PRESENTATION

Q. (Charles Huelsmann, Clinton SWCD Chairman) Is there any correlation between RCWP cost share and reduction of erosion?

A. Cost sharing has had favorable effects in places. However, overall many farmers have been changing their tillage methods, so we are not sure if RCWP had that much of an effect.

BILL BOGNER'S PRESENTATION

Q. (James Kuntz, Illinois Association of Lake Communities) Which agency do you contact for a lake survey?

A. Us -- but budget crunches will not allow us to run lake sedimentation programs unless your local committee pays for labor and supplies.

Q. (James Kuntz) Would you survey a private lake:

A. Yes -- but we still need financial assistance.

Q. (Harold Ault, Fulton County) Have you surveyed Lake Canton in Fulton County?

A. Not sure.

DONNA SEFTON'S PRESENTATION

Q. (Charles Huelsmann, Clinton County SWCD) Does your agency monitor Carlyle Lake?

A. No, the Army Corps of Engineers is responsible.

Q. (John Campbell) Has there been a study done which shows the connection between the percentage of degradation and the fish population?

A. Rich Sparks can answer that better than I can, but fish will generally deteriorate in dirty water.

RESOURCE MANAGEMENT SYSTEMS
Ronnie Murphy

Q. (Ron Laffer, former State ASCS committeeman) How have past farm programs created problems that resource management systems must try to solve?

A. USDA realizes there have been some incentives to encourage increased erosion. In my work in Nebraska, for example, interested conservationists had no choice but to plow up grasslands in order to maintain crop bases to qualify for requirements of some commodity programs. There are opportunities to tie production and conservation programs. It would be good if the various interest groups could come up with a comprehensive farm program rather than a separate commodity program and a separate conservation program. A collective approach would provide many opportunities and benefits.

Q. (John Eckes, State Conservationist-SCS) Is the USLE used to measure megarill erosion?

A. USLE only addresses sheet and rill erosion. There is a real void there. Bill Moldenhauer at Purdue and others are working on this problem trying to come up with a similar formula or model that will predict megarill erosion.

USE OF COMPUTER PROGRAMS IN EROSION CONTROL DECISION MAKING
Bart Eleveld

Q. Can I crank the capital investment of conservation practices and interest into this model?

A. Yes & No. This model can be run in two different ways. First, we can amortize all these costs over a period of years. All the income flows are discounted back to the present and we calculate our perpetuity which is equivalent to that discounted net income. So, it doesn't really reflect the cash flow problems. You can also run it for the short term, for a 1 year mode for example. In that mode, it would show what the cash net income would be for the first year of operation. There are probably some improvements that could be done in the model to improve handling the specific cash flow element of these investment type decisions.

Q. (Ken Olsen, Professor Agronomy, University of Illinois) You first made some assumptions about soil loss based on the USLE and about productivity of soil and you cranked economics into this model to predict productivity at a certain level over time. What groundwork do you really have to support this model?

A. We use information from Circular 1156 in terms of what yields will be for given topsoil depths. As economists, we are relying on physical experts to provide those relationships to us. However, this is just one aspect; as new information becomes available, we can incorporate it. The Epic Model is another model involving a detailed physical,

biological model that will be predicting what productivity losses are with different management practices. As that information becomes available, we can incorporate it into this Soilec model.

Comment by Bill Moldenhauer: We have failed to collect this data over the past 30 years, but we're working very hard to catch up with hard data. Until we do, some things going into the model will not have that kind of documentation. We are finding some of this kind of data in the files and field data is coming in. Within the next 1-3 years, we'll have more information to help validate these kinds of models.

Comment by Bart Eleveld: We're starting to look at risk implications of different conservation practices. Even though averages may be similar, we may have wider dispersions from one practice to another.

Comment by Don Holt, Ag Experiment Station: the Office of Surface Mining has provided us with a grant to work on a model of productivity using physical soil inputs. Although it is directed in general to disturbed lands, hopefully, it will be useful with other situations. If we consider eroded soil as disturbed soil, these principles ought to apply and eventually, we may be able to combine some of these physical productivity models with some of the things Bart is doing. In any case, this is a lot better than what we had before -- which was nothing.

CLOSE OF SECOND SESSION QUESTIONS AND ANSWERS

Q. (Harry Hendrickson, Association of Illinois Soil and Water Conservation Districts staff) What are the characteristics of the new type of technical services that you referred to?

A. (Jim Karr) There is a need to integrate the biological, hydrological, hydraulic and agonomic with the practices. There should be a cross disciplinary and technologic approach rather than a purely agronomic approach.

Q. (Tom Lindsey, Soil Conservation Service) What conservation practices seem to be more harmful to small streams?

A. (Jim Karr) The structural practices, especially those that violate the long term hydraulic and hydrological principles of watersheds and stream channels. I can't think of specific practices but those that impact and modify stream channels are perhaps some of the worst. They create instability that has to be continually addressed by new construction practices.

Q. (Glenn E. Stout, Director Water Resources Center, University of Illinois) Do you think we shouldn't touch our streams?

A. (Jim Karr) No, there are situations where we must work in streams such as the protection of buildings or for highway contruction. No rational person would say stream channels are inviolate. A lot of stream channel activity has been counter-productive to water resources and not very beneficial to soil resources. There are special circumstances where things have to be done in streams and the Stream Renovation Guideline handbook that I mentioned earlier discusses how to do that.

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